NUREG-1854

Standard Review Plan for Activities Related to U.S. Department of Energy Waste Determinations

Draft Report For Interim Use and Comment

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Washington, DC 20555-0001

AVAILABILITY NOTICE

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Standard Review Plan for Activities Related to U.S. Department of Energy Waste Determinations

Draft Report For Interim Use and Comment

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COMMENTS ON DRAFT REPORT

Any interested party may submit comments on this Standard Review Plan for consideration by the staff of the U.S. Nuclear Regulatory Commission. Comments may be accompanied by additional relevant information or supporting data. Please specify the report number (Draft NUREG-1854) in your comments and send them by the end of the 60-day comment period specified in the *Federal Register* notice announcing availability of this draft to the following address:

Chief, Rules Review and Directives Branch
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Electronic comments may be submitted to nrcrep@nrc.gov.

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ABSTRACT

This Standard Review Plan (SRP) provides guidance to the staff of the U.S. Nuclear Regulatory Commission (NRC) for conducting activities related to waste determinations. Waste determinations are evaluations performed by the U.S. Department of Energy and are used to assess whether certain wastes resulting from the reprocessing of spent nuclear fuel can be considered low-level waste and managed accordingly. This SRP applies to NRC activities conducted for the Savannah River Site (SRS) in South Carolina and the Idaho National Laboratory (INL) in Idaho pursuant to the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA), as well as the Hanford site in Washington, and the West Valley site in New York. The SRP provides information regarding the background and history of waste determinations, the different applicable criteria and how they are applied and evaluated, the review of associated performance assessments and inadvertent intruder analyses, removal of highly radioactive radionuclides, and NRC's monitoring activities that will be performed at SRS and INL in accordance with the NDAA.

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ABBREVIATIONS/ACRONYMS

ALARA	As Low as Is Reasonably Achievable
BTP	Branch Technical Position
CFR	Code of Federal Regulations
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
HLW	High-level Waste
IA	Interagency Agreement
INL	Idaho National Laboratory
LLW	Low-level Waste
MOU	Memorandum of Understanding
NAS	National Academy of Sciences
NDAA	Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005
NRC	U.S. Nuclear Regulatory Commission
PA	Performance Assessment
RAI	Request for Additional Information
SRM	Staff Requirements Memorandum
SRP	Standard Review Plan
SRS	Savannah River Site
TER	Technical Evaluation Report
TRU	Transuranic
USGS	U.S. Geological Survey
WIR	Waste Incidental to Reprocessing

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INTRODUCTION

Foreword

In October 2004, the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA) was enacted. Section 3116 of the NDAA gave the U.S. Nuclear Regulatory Commission (NRC) new responsibilities with respect to U.S. Department of Energy (DOE) waste management activities for certain “incidental” waste resulting from the reprocessing of spent nuclear fuel within the States of South Carolina and Idaho (see Appendix for the text of Section 3116 of the NDAA). NRC’s responsibilities include consultation with DOE on the determination of whether waste is high-level waste (HLW), as well as monitoring of DOE’s disposal actions for these wastes. The concept behind incidental waste is that some material, resulting from the reprocessing of spent nuclear fuel, does not need to be disposed of as HLW in a geologic repository because the residual radioactive contamination, if properly isolated from the environment, is sufficiently low so that it does not represent a hazard to public health and safety. Consequently, incidental waste is not considered to be HLW but instead is low-level waste (LLW) or, in DOE’s waste classification scheme, transuranic (TRU) waste. DOE uses technical analyses that are documented in a “waste determination” to evaluate whether waste is incidental or alternatively, is HLW. A waste determination is DOE’s analysis whether the waste will meet the applicable incidental waste criteria.

Prior to passage of the NDAA, DOE would periodically request NRC to provide technical advice for specific waste determinations. The staff reviewed DOE’s waste determinations to assess whether there were sound technical assumptions, analysis, and conclusions with regard to meeting the applicable incidental waste criteria. The staff typically evaluated information submitted by DOE, generated requests for additional information (RAIs), met with DOE representatives to discuss technical questions and issues, and documented the final review results in Technical Evaluation Reports (TERs). NRC’s advice was provided in an advisory manner and did not constitute regulatory approval. These types of reviews were completed for waste intended to be removed from tanks at Hanford (NRC, 1997a), tank closure at the Savannah River Site (SRS) (NRC, 2000a), waste intended to be removed from tanks at Idaho National Laboratory (INL) (NRC, 2002a), and tank closure at INL (NRC, 2003a).

Because the NRC expects enactment of the NDAA to increase the number of waste determinations submitted to NRC for review, NRC has decided to develop this draft Standard Review Plan (SRP or review plan). This SRP will provide guidance to NRC staff on how to conduct a technical review of a waste determination, as well as how to conduct monitoring activities under the NDAA, and will help ensure consistency across different reviews and different reviewers. Because the technical aspects of NRC’s waste determination reviews are expected to be similar for all four sites, regardless of whether the site is covered by the NDAA, this SRP will address reviews for SRS, INL, the Hanford site, and the West Valley Demonstration Project.

In November 2005, the NRC held a public scoping meeting in Rockville, MD, to obtain public input on the scope of the SRP. In addition, NRC published a *Federal Register* notice on November 2, 2005, announcing the scoping meeting and stating that written comments on the scope of the SRP would be accepted until November 25, 2005 (NRC, 2005a). The transcript of the scoping meeting is publicly available in NRC’s Agencywide Document Access and

Management System (ADAMS) (NRC, 2005b). NRC received written comments on the proposed scope of the SRP from the SRS Citizens Advisory Board (CAB, 2005), the South Carolina Department of Health and Environmental Control (SCDHEC, 2005), and the Washington State Department of Ecology (Washington, 2005), and the comments are publicly available in ADAMS.

In December 2005, the NRC published a *Federal Register* notice issuing draft interim guidance for performing concentration averaging for waste determinations (NRC, 2005c). The *Federal Register* notice was issued due to high stakeholder interest in obtaining the guidance as soon as practicable due to the ongoing development of waste determinations. The draft interim guidance was open for public comment until January 31, 2006. NRC received comment letters from the State of Idaho Department of Environmental Quality (Idaho, 2006), the State of Washington Department of Ecology (Washington, 2006), the State of Oregon Department of Energy (Oregon, 2006), Washington Closure Hanford (WCH, 2006), the Natural Resources Defense Council (NRDC, 2006), and members of the public (Greeves, et al, 2006), and the comment letters are publicly available in ADAMS. As discussed in the *Federal Register* notice, the concentration averaging guidance is included in this draft SRP and is open again for public comment (see Section 3.5.1.1). The comments received to date will be considered along with the comments on this draft SRP. This draft SRP makes only minor editorial changes to the text of the concentration averaging guidance.

This draft SRP provides guidance for the NRC staff and does not set forth regulatory requirements for NRC nor DOE, and compliance with this review plan is not required. This draft SRP is being released for a 60-day public comment period. The final SRP will be issued after the NRC staff takes into consideration any public comments received, as appropriate.

Larry W. Camper, Director
Division of Waste Management and
  Environmental Protection
Office of Nuclear Material Safety
  and Safeguards

How to Use this Standard Review Plan

This draft SRP provides guidance to the NRC staff when evaluating waste determinations developed by the DOE for SRS, INL, Hanford, and West Valley. The review plan provides elements the staff should review to determine whether there is reasonable assurance that the appropriate criteria can be met. This review plan also provides information about the NRC's role in the waste determination process and NRC's monitoring activities under the NDAA.

This review plan provides guidance for the NRC staff. It does not set forth regulatory requirements for NRC nor DOE, and compliance with this review plan is not required. Methods and approaches different from those described here could be acceptable to demonstrate that there is reasonable assurance that the appropriate criteria can be met. Waste determinations typically use the performance objectives of 10 CFR Part 61, Subpart C, as a criterion that must be met (see Section 2); references to other parts of the regulations in 10 CFR Part 61 (i.e., other than Subpart C) are included only to provide information and guidance as they relate to the staff reviews.

This review plan is risk-informed and performance-based to ensure that the NRC review is focused on those aspects most important to health and safety. The staff intends to perform its reviews in such a way that risk insights are incorporated into the review process and into the development of the staff's conclusions. Because this review plan will be used to review a potentially large number of different types of waste determinations, its scope is general enough to allow the NRC staff to apply the guidance to a wide range of DOE waste determinations while also containing sufficient detail to ensure thoroughness and consistency of the staff's reviews.

Section 1 of this review plan covers the site information needed to provide context to the reviewer and to support a performance assessment. Section 2 discusses the incidental waste criteria. Section 3 provides information on assessing removal of radionuclides and on estimating waste classification. Sections 4-7 address the performance objectives of 10 CFR Part 61, Subpart C. Section 4 of the review plan provides guidance for the staff review of the long-term performance assessment in order to evaluate the protection of the general population (10 CFR 61.41). Section 5 provides guidance for the staff review of assessments of potential radiation exposures to an inadvertent intruder (10 CFR 61.42). The review procedures presented in Section 6 are for assessing compliance with the radiation protection standards during operations (10 CFR 61.43). Section 7 of the review plan provides guidance for assessing long-term site stability (10 CFR 61.44). Guidance for assessing the implementation of DOE quality assurance programs is in Section 8, and a brief summary of how the NRC review will be conducted and documented is provided in Section 9. Information regarding monitoring activities is provided in Section 10.

Structure of the SRP

Where applicable, sections of this review plan are divided into two subsections that describe the steps of the review process.

Areas of Review. This subsection describes the scope of the review (i.e., what is to be reviewed). It contains a brief discussion of the specific types of technical information and analyses that should be reviewed. The areas listed are intended to be used for broad application; therefore, the listing is not exhaustive and may be supplemented for a given review, as appropriate.

Review Procedures. This subsection discusses the appropriate review topics and techniques. The reviewer should generally determine that the topics listed in this section are evaluated, or that there is adequate technical basis for a conclusion that a specific topic does not need to be addressed. The reviewer should evaluate whether the information provided is sufficient to support the conclusions presented in the waste determination.

This review plan covers a variety of site conditions and facility designs. Each section provides review procedures for areas of review pertinent to that section. Because the reviews are conducted on a case-by-case basis, the reviewer may emphasize particular aspects of each review plan section as appropriate. Where possible, the proposed review procedures are based on applicable existing NRC guidance and previous NRC experience gained from reviews of DOE waste determinations.

Updating the SRP

This review plan will be revised and updated periodically to clarify the content or incorporate modifications as the need arises. A revision number and publication date will be issued as needed.

Background

The concept of incidental waste, also known as waste-incidental-to-reprocessing (WIR) or non-high-level waste (non-HLW), is that some wastes can be managed based on their risk to human health and the environment, rather than based on the origin of the wastes. With respect to wastes resulting from the reprocessing of spent nuclear fuel, such as the tank residuals at some DOE sites, some are highly radioactive and need to be treated and disposed of as HLW in a geologic repository but others do not. Incidental waste does not pose the same amount of risk to human health and the environment as HLW, and does not need to be disposed of as HLW in order to manage the risks that it poses. Consequently, incidental waste is not considered to be HLW. DOE uses technical analyses documented in a “waste determination” to evaluate whether waste is incidental or HLW. A waste determination is DOE’s analysis as to whether the waste will meet the applicable incidental waste criteria and usually includes a performance assessment. A performance assessment is a quantitative evaluation of potential releases into the environment and the resultant radiological doses, and it often is performed using a computer model.

The concept of incidental waste has been recognized since 1969 when the Atomic Energy Commission, NRC’s predecessor agency, issued for comment a draft policy statement regarding the siting of reprocessing facilities in the form of a proposed Appendix D to 10 CFR Part 50 which addressed a definition of HLW (AEC, 1969). The draft policy statement provided that certain materials resulting from reprocessing could be disposed of in accordance with 10 CFR Part 20 requirements. Although the draft policy statement did not use the term “incidental,” the Commission intended that the term HLW not include certain wastes which were incidental to reprocessing operations. However, when Appendix D was finalized as Appendix F, it did not include the paragraphs on incidental waste because the Commission wanted to preserve its flexibility as to how such material should be treated. The term "incidental waste" was apparently first used in NRC's 1987 advance notice of proposed rulemaking to redefine the definition of HLW (NRC, 1987). However, in the 1989 final rulemaking action on disposal of radioactive waste, the Commission did not redefine HLW (NRC, 1989).

In 1990, the States of Oregon and Washington petitioned the Commission to amend 10 CFR Part 60 to redefine HLW. The petition concerned whether Hanford tank waste was subject to NRC licensing jurisdiction. In response to the petition, the Commission approved specific criteria for determining whether waste was incidental and issued a Staff Requirements Memorandum (SRM) dated February 16, 1993, in response to SECY-92-391, "Denial of PRM 60-4: Petition for Rulemaking from the States of Washington and Oregon Regarding Classification of Radioactive Waste at Hanford." NRC published the criteria in the *Federal Register* as part of the petition denial, as follows (NRC, 1993):

(1) The waste has been processed (or will be further processed) to remove key radionuclides to the maximum extent that is technically and economically practical,

(2) The waste will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C low-level radioactive waste (LLW) as set out in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 61, and

(3) The waste is to be managed, pursuant to the Atomic Energy Act, so that safety requirements comparable to the performance objectives set out in 10 CFR Part 61, are satisfied.

The performance objectives of 10 CFR Part 61, Subpart C, include provisions for protecting the general population from releases of radioactivity, protecting individuals from inadvertent intrusion, and protecting individuals during operations. The performance objectives also include provisions for the stability of the site after closure.

In a May 30, 2000, SRM on SECY-99-0284, "Classification of Savannah River Residual Tank Waste as Incidental," the Commission indicated that a more performance-based approach should be taken to determine whether waste could be classified as incidental (NRC, 2000b). In effect, cleanup to the maximum extent that is technically and economically practical and demonstration that performance objectives could be met (consistent with those which the Commission demands for the disposal of LLW) should serve to provide adequate protection of the public health and safety and the environment. In the Final Policy Statement for the Decommissioning Criteria for the West Valley Demonstration Project at the West Valley Site, the Commission adopted this performance-based approach and stated the criteria that should be applied to the incidental waste determinations at West Valley, as follows (NRC, 2002b):

(1) The waste should be processed (or should be further processed) to remove key radionuclides to the maximum extent that is technically and economically practical; and

(2) The waste should be managed so that safety requirements comparable to the performance objectives in 10 CFR Part 61, Subpart C, are satisfied.

In July 1999, DOE issued DOE Order 435.1, "Radioactive Waste Management" and the associated Manual, DOE M 435.1-1, "Radioactive Waste Management Manual," both of which were subsequently revised in 2001 (DOE 2001a, 2001b). DOE M 435.1-1 states that waste determined to be incidental to reprocessing is not HLW and shall be managed in accordance with the requirements for TRU waste or LLW if it meets appropriate criteria. DOE M 435.1-1 discusses DOE's incidental waste evaluation process and the criteria for a determination of whether waste is incidental to reprocessing.

Prior to the passage of the NDAA (see the discussion below), DOE had periodically requested NRC provide technical reviews of specific waste determinations. NRC provided technical assistance and advice to DOE regarding its waste determinations and did not provide regulatory approval for DOE's actions. NRC's reviews were generally performed by the Office of Nuclear Material Safety and Safeguards under site-specific reimbursable Interagency Agreements (IAs) and Memoranda of Understanding (MOUs).

The staff reviewed DOE's waste determinations to assess whether DOE's technical assumptions, analyses, and conclusions were reasonable and whether there was reasonable assurance that the applicable criteria could be met. In general, the staff examined technical areas such as estimated radionuclide inventory, technology alternatives, performance assessment methodology, engineered system performance, infiltration, release and transport parameters, receptor scenarios and assumptions, and uncertainty and sensitivity analysis. The staff typically evaluated information submitted by DOE, generated requests for additional information (RAIs), met with DOE representatives to discuss technical questions and issues, and documented the final review results in Technical Evaluation Reports (TERs). Typically, the staff provided the associated MOUs, IAs, and TERs to the Commission for review before taking action. In addition to the review of the SRS tank closure methodology discussed above (NRC, 1999), the staff developed Commission papers for reviews of incidental waste determinations for waste intended to be removed from tanks at Hanford (NRC, 1997b), sodium-bearing wastes at the Idaho National Laboratory (INL) (NRC, 2002c), and tank farm closure at INL (NRC, 2003b). After completing any changes directed by the Commission, the NRC staff transmitted the final TERs to DOE (NRC, 1997a, 2000a, 2002a, 2003a).

The Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005

In 2004, Senator Lindsey Graham of South Carolina introduced legislation that would allow DOE to use a process similar to the incidental waste process in DOE Order 435.1 at the Savannah River Site (SRS). During the development of the legislation, Congress inquired about the U.S. Nuclear Regulatory Commission's (NRC's) position on incidental waste and the proposed legislation, and the Commission responded in letters to Senator Inhofe on May 18, 2004 and Senator Jeffords on July 15, 2004 (NRC, 2004a, 2004b).

The NDAA was passed by Congress on October 9, 2004, and signed by the President on October 28, 2004. Section 3116 of the NDAA allows DOE to continue to use an incidental waste process to determine that waste is not HLW; however, the NDAA is applicable to only South Carolina and Idaho and does not apply to waste transported out of these States. The

NDAA requires that: (1) DOE consult with NRC on its non-HLW determinations and plans, and (2) NRC, in coordination with the State, monitor disposal actions taken by DOE for the purpose of assessing compliance with NRC regulations in 10 CFR Part 61, Subpart C. If NRC determines that any disposal actions taken by DOE are not in compliance, NRC shall inform DOE, the State, and Congressional subcommittees as soon as practicable. In addition, the NDAA provides for judicial review of any failure of NRC to carry out its monitoring responsibilities. The NDAA is provided in the appendix of this review plan.

The criteria contained in the NDAA for determining whether waste is non-HLW are similar to the incidental waste criteria previously used by NRC and specify that such waste:

(1) Does not require permanent isolation in a deep geologic repository for spent fuel or HLW;

(2) Has had highly radioactive radionuclides removed to the maximum extent practical; and

(3)A Does not exceed concentration limits for Class C low-level waste (LLW) and will be disposed of in compliance with the performance objectives in 10 CFR Part 61, Subpart C; or

(3)B Exceeds concentration limits for Class C LLW but will be disposed of in compliance with the performance objectives of 10 CFR Part 61, Subpart C, and pursuant to plans developed by DOE in consultation with the NRC.

After enactment of the NDAA, the NRC staff developed an implementation plan that describes how the staff would carry out its new responsibilities. That plan was described in SECY-05-0073, dated April 28, 2005 (NRC, 2005d). The Commission commented on and approved the staff's proposed plans in a SRM dated June 30, 2005 (NRC, 2005e).

Role of the U.S. Nuclear Regulatory Commission

The four DOE sites that potentially have incidental waste are operating under different requirements for evaluation and management of the waste. SRS and INL may use the requirements of the NDAA for waste being disposed of in the State, but could possibly use DOE Order 435.1 for waste being shipped out of the State or possibly for certain wastes remaining in the State that are not covered by the NDAA (e.g., waste not covered by a State issued closure plan or permit, as stated in the NDAA). Hanford is not covered under the NDAA and could use the requirements of DOE Order 435.1. West Valley will use NRC's Final Policy Statement for the Decommissioning Criteria for the West Valley Demonstration Project at the West Valley Site (the West Valley Policy Statement) for waste being disposed of on site, and may use DOE Order 435.1 for waste being sent off site. Alternatively, it may be that DOE decides to apply the requirements of the NDAA to all of its sites for consistency. The role of NRC and the scope of the staff's reviews may vary depending on the criteria being applied in a specific waste determination.

The NDAA applies only to waste remaining in South Carolina and Idaho. Under the NDAA, the NRC has a statutory obligation to provide consultation to DOE for such waste. NRC performs a technical review of DOE's waste determinations and arrives at an independent conclusion as to whether there is reasonable assurance that the criteria of the NDAA can be met by DOE's waste management approach. Guidance on performing technical reviews under the NDAA is provided in this review plan. Also, NRC must monitor DOE's disposal actions for such waste to assess compliance with the performance objectives of 10 CFR Part 61, Subpart C. The NRC must report any noncompliance to Congressional subcommittees, the State, and DOE as soon as practicable after discovery of the noncompliance. Monitoring is discussed in more detail in Section 10.

For the West Valley site, NRC's Final Policy Statement for the Decommissioning Criteria for the West Valley Demonstration Project at the West Valley Site applies to any residual material remaining at the site, including any incidental waste (NRC, 2002b). Currently at West Valley, DOE is acting as a surrogate for the licensee (the New York State Energy Research and Development Authority), and NRC is in an advisory role with respect to DOE's incidental waste determinations. When providing the incidental waste criteria, the West Valley Policy Statement states that "it is the Commission's expectation that it will apply this criteria at the WVDP at the site following the completion of DOE's site activities" (NRC, 2002b). Guidance on performing technical reviews under the West Valley Policy Statement is provided in this review plan. For waste that is disposed of off site, it is DOE's responsibility to determine which criteria are applicable; for example, DOE may decide to apply DOE Order 435.1. Guidance on performing technical reviews under DOE Order 435.1 also is provided in this review plan. For waste determinations performed using DOE Order 435.1 at the West Valley site, NRC provides technical advice and consultation in an advisory manner.

At Hanford, DOE is responsible for determining which criteria are applicable to incidental waste determinations. The Hanford Federal Facility Agreement and Consent Order (the Tri-Party Agreement) was entered into by DOE, the U.S. Environmental Protection Agency, and the State of Washington Department of Ecology in 1989. Appendix H of the Tri-Party Agreement requires that DOE "establish an interface with the [NRC], and reach formal agreement on the retrieval and closure actions for single shell tanks with respect to allowable waste residuals in the tank and soil column" for those tanks for which DOE could not remove 99% of the waste by volume (DOE, 1989). NRC provides technical advice and consultation in an advisory manner for any waste determination reviews performed for the Hanford site.

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1 SITE-SPECIFIC AND GENERAL INFORMATION

1.1 Site-Specific System Description Information

This section of the review plan describes information about a site, disposal facilities[1], and waste management activities that a reviewer should evaluate at the beginning of a waste determination review. The intent of the review described in this section is to ensure that a reviewer establishes the proper context for the detailed technical review that should be performed according to the guidance provided in Sections 2–8 of this review plan. In general, to establish an appropriate context for a detailed technical review, the reviewer must understand how the proposed waste management activities, disposal facility design, natural site characteristics, performance assessment analyses, and inadvertent intruder analyses are used to support decisions made based on the waste determination. If practical, the reviewer should visit the site during the review. The site visit should provide the reviewer with an opportunity to see many of the site features and is expected to facilitate the review of information related to the waste determination.

1.1.1 Brief Description and Scope

The reviewer should begin by assessing the decisions to be made based on the waste determination and identifying the technical bases for those decisions. Thus, the reviewer should evaluate the purpose and scope of the proposed waste management activities, the U.S. Department of Energy's (DOE's) understanding of the applicable waste criteria for the waste determination (see Section 2), and how the proposed waste management activities meet the applicable criteria. Based on previous waste determinations, NRC anticipates that DOE may provide this information in one or more summary documents (e.g., as in DOE, 2005a–c; Rosenberger, et al., 2005; Buice, et al., 2005). Specifically, before beginning a detailed technical review, the reviewer should be familiar with the following information:

- A brief description of the disposal site and surrounding areas, including the size of the disposal facility and the location of the disposal facility on the larger DOE site;

- DOE's definition of the scope of the waste determination, including an identification of the waste streams to which decisions based on the waste determination will apply;

- A description of the purpose of the proposed waste management activities;

- A description of the major structures, systems, and components of the proposed disposal facilities;

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[1] In this review plan, unless otherwise specified, the scope of the terms "site" and "facilities" is limited to those locations, facilities, disposal units, and barriers immediately related to the DOE waste determination under review, and the features that could affect the performance of the proposed disposal facility (e.g., aquifers, rivers). Unless otherwise noted, the term "site" is not intended to apply to the much larger area under DOE control and ownership, such as the Savannah River Site or Idaho National Laboratory, except to the extent that features of the larger DOE site may affect the performance of the proposed disposal facility. In this review plan, the term "DOE site" is used to refer to the entire area under DOE control.

- The proposed schedule for relevant waste management activities;

- Which criteria are applicable to the waste determination (see Section 2); and

- An assessment of compliance with the applicable waste criteria, including the following:

  S A list of the radionuclides considered to be highly radioactive radionuclides in the context of the waste determination and a summary of the basis for their selection (see Sections 2.4.2 and 3.2);

  – A summary of waste removal activities, including inventories of radionuclides before and after removal (see Section 3);

  – The waste classification assumed by DOE, if applicable (see Section 3.5);

  – A summary of results of the long-term performance assessment and inadvertent intruder analyses used to demonstrate compliance with the applicable performance objectives (see Sections 4 and 5);

  – The major features of the proposed activities that will ensure the safety of individuals during operations (see Section 6);

  S A summary of the pathways and radionuclides that dominate predicted doses to members of the public and workers during operations and to members of the public (including inadvertent intruders) after site closure (see Sections 4, 5, and 6);

  S A summary of natural and engineered features of the disposal site that significantly limit or prevent potential doses to individuals after site closure (see Section 4.6.1.1); and

  – The major features of the natural system and relevant waste disposal facilities that could either impact or ensure disposal site stability (see Section 7).

1.1.2 Facility Description

The reviewer should evaluate the facility description to understand the role of the disposal facility in the long-term performance assessment, inadvertent intruder analysis, protection of individuals during operations, and disposal site stability. In general, the areas of review are expected to encompass, but not necessarily be limited to, the technical information described in 10 CFR 61.12(b), (c), (d), (g), and (i). Specifically, the reviewer should evaluate the following information:

- A scale drawing or map of the relevant disposal unit(s) showing locations of radioactivity within the disposal unit(s), including a description of structures (e.g., equipment, tanks, pumps, piping, or disposal vaults) at the facility that are the subject of the waste determination;

- A system description, including the geometry of structures (e.g., tanks, contaminated equipment, or waste treatment facilities), and barriers (e.g., caps or vaults), that may be important in developing conceptual models to assess the performance of the facility;

- A description of the major design features of the disposal facility and disposal units, and the relationship between the design features and performance objectives, including the following:

  – A description of design features related to the infiltration of water, integrity of covers for disposal units, and disposal site drainage;

  – A description of the design features related to disposal site closure including features designed to limit the need for long-term maintenance and the potential for inadvertent intrusion;

  – A description of design features related to disposal site stabilization, including the structural stability of backfill, wastes, and covers;

- A description of the relationship between natural events and processes (see Section 1.1.3) and the principal facility design criteria;

- A description of the physical and chemical forms of the radionuclides to the extent that they affect source term and transport properties;

- Information about past waste management activities (e.g., addition of organic chelating agents, waste treatment processes) to the extent that they may affect contaminant fate and transport modeling or affect monitoring activities; and

- Information about previous waste releases that is relevant to potential release pathways or to contamination that may affect proposed waste management activities.

In some instances, existing facilities, and especially older facilities, may not be adequately described. If the information provided is incomplete, the reviewer should determine what conservative assumptions are necessary to assess long-term facility performance.

1.1.3 Site Description

The reviewer should evaluate the natural and anthropogenic characteristics of the proposed disposal site that may affect its ability to meet the performance objectives of 10 CFR Part 61, Subpart C. It is expected that the reviewer will need the information described in this section to evaluate conceptual models supporting a performance assessment (e.g., hydrologic characteristics influencing radionuclide transport), inadvertent intruder analysis (e.g., the presence of natural resources that could influence methods of inadvertent intrusion), evaluation of doses to individuals during operations (e.g., the location of members of the public during operations), and evaluation of site stability (e.g., the nature of meteorological, hydrologic, and seismic disruptive events). It is anticipated that (1) the effect of individual natural and anthropogenic features on waste isolation will be different at different disposal sites and (2) the level of description provided may vary accordingly. In general, the areas of review are expected to encompass, but not necessarily be limited to, the technical information described in 10 CFR 61.12(a), (d), and (h). Additional guidance on reviewing these types of information is provided in other documents (see NRC, 2003a, 2000, 1988, 1982, 1981).

1.1.3.1 Site Location and Description

The reviewer should evaluate information related to the site location to understand the relationship between the disposal site and regional features and to establish potential locations of receptors during operations and after site closure. To the extent possible, the reviewer should verify the information with independent reports (e.g., U.S. Geological Survey [USGS] maps, site maps, previous waste determinations, site planning documents). Specifically, the reviewer should evaluate the following information:

- A scale drawing or map of the waste disposal system and related existing or proposed structures, showing sizes and locations on the DOE site;

- A scale drawing or map showing the location of the disposal site relative to prominent natural features such as rivers and lakes;

- A map that shows the topography (including elevations) of the site;

- A description of the man-made features of the site that may affect the waste isolation characteristics of the disposal site, such as parking lots or roads that may affect runoff and recharge;

- A description of neighboring property surrounding the DOE site;

- A description of biological characteristics of the area that may influence waste isolation (e.g., a description of any plants native to the region that could compromise closure caps through root intrusion, or the presence of burrowing animals that could compromise closure caps or exhume waste); and

- A scale drawing or map that shows the location of members of the public before and after site closure and before and after the period of institutional controls ends, including the location of inadvertent intruders after the period of institutional controls ends.

1.1.3.2 Land Use

The reviewer should evaluate past, current, and potential future land use around the site to provide context for assumptions about the activities of members of the public (including potential inadvertent intruders) after site closure, and members of the public during operations. The reviewer should verify that DOE has used appropriate available data on land use to support its performance assessment and inadvertent intruder analyses. Specifically, the reviewer should perform the following review procedures:

- The reviewer should evaluate the uses of land prior to Federal control of the site and whether any changes to the site have been made that would preclude the resumption of similar activities (e.g., depletion of an aquifer).

- The reviewer should assess the current uses of land neighboring the DOE site and the impact these uses may have on future use of the disposal site after the end of institutional controls (e.g., the growth of a major metropolitan area neighboring the DOE site could limit agricultural uses of the disposal site).

- The reviewer should assess the current uses of land neighboring the DOE site and any impact the current land uses may have on assumptions about the location of members of the public during operations.

- The reviewer should evaluate a description of ground and surface waters on or near the site including information on resource type, occurrence, location, current projected uses, and potential future uses (e.g., agricultural, industrial, drinking water source).

- The reviewer should evaluate a description of the natural resources occurring at or near the site (e.g., metallic and nonmetallic ores, fossil fuels and hydrocarbons, and industrial mineral deposits) and assess whether the exploitation of natural resources at the site could affect future development of land surrounding the disposal site.

- The reviewer should evaluate a description of these natural resources occurring at or near the site and assess whether the exploitation of the resources could affect the likelihood or potential methods of inadvertent intrusion into the disposal site.

1.1.3.3 Meteorology and Climatology

The reviewer should evaluate a description of the meteorology and climatology in the vicinity of the site to determine how local weather patterns could affect the ability of the site to meet the performance objectives in 10 CFR Part 61, Subpart C. Thus, the reviewer should examine meteorological information necessary to support estimates of infiltration, airborne dose pathway analyses, and potential disruption of engineered barriers by processes such as flooding, erosion, and frost heaving. Because of the long timeframes to be considered, the reviewer also should verify whether DOE has provided a description of its projections of naturally-induced future climate changes and appropriately incorporated these projections into the performance assessment. Specifically, the reviewer should evaluate the following information:

- A description of the general climate of the region;

- A description of aspects of the local (site) meteorology that may affect performance assessment and dose calculations (e.g., temperature, precipitation intensity and duration, wind speed, wind direction, and atmospheric stability); and

- A description of the projected future climate states to be considered in the performance assessments.

To the extent possible, the reviewer should verify descriptions of the site-specific meteorology and climatology information against independent information (e.g., information provided by the National Weather Service or the National Oceanic and Atmospheric Administration). Projected future climate states should be supported by an adequate technical basis and compared to independent assessments (e.g., paleoclimate modeling performed by the National Climatic Data Center), to the extent possible.

1.1.3.4 Geology and Seismology

Information about geologic processes (e.g., earthquakes, erosion, faulting) that occur at the site is needed to support an assessment of site stability and to support the development of conceptual models used in the performance assessment and inadvertent intruder analysis. To support an assessment of how the geological and geotechnical characteristics of a site will affect its performance, the reviewer should evaluate the following information:

- A description of the surface and subsurface geologic characteristics and stratigraphy of the site and its vicinity;

- A description of the geomorphology of the site, including USGS topographic maps that emphasize local geomorphic features pertinent to the site, particularly for processes such as erosion that may affect long-term site stability;

- A discussion of the structural geology, tectonic history, and seismicity of the region. Specifically, the relationship between seismicity and tectonic structures and the earthquake-generating potential of any active structures should be reviewed;

- A description of man-made geologic features, such as mines or quarries, that may affect water runoff and recharge; and

- A description of the structural stability of geotechnical features of the disposal facility (e.g., slope stability, potential for subsidence of backfilled soils that could affect cap stability).

To the extent possible, the reviewer should verify descriptions of the site-specific geological and seismological information with independent information, such as maps and other geospatial data generated by the USGS.

1.1.3.5 Hydrology

The reviewer should use information about the surface water and groundwater hydrology to evaluate conceptual models of how the hydrological characteristics at the site will affect site stability and radionuclide release and transport. Depending on the specific site, the reviewer may need to analyze the potential impact of atypical hydrological conditions (e.g., floods). Specifically, the reviewer should evaluate the following information:

- A description of natural drainage and surrounding watershed fluvial features, and anthropogenic features that may influence surface hydrology and the potential for flooding at the site;

- Water resource data, including maps, hydrographs, and stream records from other agencies (e.g., USGS and U.S. Army Corps of Engineers);

- A description of the surface water bodies at the site and surrounding areas, including the location, size, shape, and other hydrologic characteristics of streams, lakes, or coastal areas;

- A description of the saturated zone including potentially affected aquifers, the lateral extent, thickness, water-transmitting properties, recharge and discharge zones, groundwater flow directions and velocities, and other information that can be used to support the conceptual model of the saturated zone;

- Physical parameters, such as storage coefficients, transmissivities, hydraulic conductivities, porosities, and intrinsic permeabilities;

- A description of the unsaturated zone, including descriptions of the lateral extent and thickness of permeable and impermeable zones, the presence, lateral extent, and thickness of perched water zones, potential conduits of anomalously high flux, and direction and velocity of unsaturated flow;

- Physical parameters, such as porosity, water content (including temporal variation); saturated hydraulic conductivity; characteristic relationships between water content, pressure head, and hydraulic conductivity; and hysteretic behavior during wetting and drying cycles; and

- The distribution coefficients (K_d) of the radionuclides of interest and the associated technical basis for their selection (e.g., site-specific values, literature compilations, geochemical models).

1.1.3.6 Radiological Status

Because the DOE sites relevant to this review plan (Savannah River Site, Idaho National Laboratory, Hanford, and West Valley) have been in operation for decades, areas near the proposed disposal facility may already be contaminated with radioactive material. In general, contamination resulting from spills or other releases of radioactive material at the site are addressed through alternate regulatory processes and is not within the scope of waste determinations. However, existing radioactive contamination may affect or provide useful information about the waste management activities proposed in a waste determination. Specifically, the reviewer should evaluate information about groundwater contamination that may be used to provide relevant information about radionuclide release pathways, constrain contaminant fate and transport models, or that may complicate subsequent monitoring activities. Therefore, a reviewer should evaluate information about the current radiological status of the area near the proposed disposal facility and its environs, including the following information:

- A summary of areas near the proposed disposal facilities where releases of radioactive material occurred in the past;

- A description of the types, forms, activities, and concentrations of radionuclides involved in the release; and

- A scale drawing or map of the site, facilities, and environs showing the locations of relevant previous releases, including features such as abandoned boreholes or disturbed soil that may affect contaminant fate and transport.

- To ensure completeness of information describing the area near the proposed disposal facility, the reviewer should evaluate the purpose, major attributes, summary conclusions, and regulatory program under which studies of existing contamination near the disposal facility were performed.

- If significant groundwater contamination exists, the reviewer also should evaluate historical information about plume movement for comparison with the results of site-specific groundwater models used to support the performance assessment (see Section 4) and DOE's plans to monitor and model plume movement for coordination with NRC monitoring activities (see Section 10).

1.2 Applicable Sites and Waste Criteria

This review plan has been developed to address the reviews of waste determinations for the four DOE sites that may have incidental waste:

- Savannah River Site (SRS), Aiken, SC;

- Idaho National Laboratory (INL), Idaho Falls, ID;

- Hanford Site (Hanford), Richland, WA; and

- West Valley Demonstration Project (West Valley), West Valley, NY.

The purpose of this section of the review plan is to determine whether DOE is using the applicable waste criteria for a given waste determination. The different sets of waste criteria are discussed in more detail in Section 2 of this review plan. Guidance for the detailed technical evaluation of whether there is reasonable assurance that the applicable waste criteria can be met is provided in Sections 2–8 of this review plan.

Based on previous waste determinations, it is anticipated that DOE will provide information that addresses each of the waste criteria it considers to be applicable to a specific waste determination. The staff should review the DOE waste determination to verify that the applicable waste criteria have been addressed. For example, the staff should confirm whether DOE has identified the following criteria for specific sites:

- The Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA) (Public Law 108-375, 2004) is applicable to certain waste disposed of in South Carolina or Idaho subject to other requirements of the NDAA (see Section 2.1);

- The waste incidental to reprocessing criteria from DOE Order 435.1 and its associated Manual (DOE, 2001a, 2001b) may apply to waste in South Carolina or Idaho that is not covered by the NDAA, waste at Hanford, or waste being shipped off site from the West Valley Demonstration Project (see Section 2.2); and

- The waste incidental to reprocessing criteria identified in the Decommissioning Criteria for the West Valley Demonstration Project at the West Valley Site; Final Policy Statement (NRC, 2002) are applicable to waste being disposed of on site at the West Valley site (see Section 2.3).

1.3 Prior Waste Determinations

The purpose of this section is to assure that reviewers appropriately consider relevant information from previous waste determinations and reviews. The reviewer should consider prior waste determination reviews for relevance to the technical evaluation at hand and how they might support an assessment of the DOE demonstration of compliance with appropriate waste criteria. For example, the reviewer could examine NRC's Technical Evaluation Reports (TERs) for tank closure at INL (NRC, 2003b) and for salt waste disposal at SRS (NRC, 2005). As additional waste determination reviews are completed, there will be additional documents available for each of the four DOE sites to be considered.

To the extent practical, the staff should evaluate prior TERs both to gain insights from previous NRC conclusions and recommendations and to understand any major changes from prior analyses. Particular attention should be focused on the extent to which the prior reviews provide insights into the current DOE waste determination with regard to information such as, but not limited to, the following:

- Site characterization;

- Waste inventory and source term;

- Locations, descriptions, operating history, and radiological status of any facilities associated with the proposed waste management activities;

- Existing and proposed waste management strategies and methodologies;

- Existing and proposed performance assessment and dose modeling methodologies and results;

- Existing and proposed monitoring systems; and

- Related structures and processes employed by DOE in previous waste management strategies.

This evaluation may include prior waste determination reviews identified by either DOE or the reviewer. To the extent practical, the reviewer should consider prior waste determinations from both the site being currently evaluated and other DOE sites, if relevant.

1.4 References

Buice, J.M., R.K. Cauthen, R.R. Haddock, B.A., Martin, J.A. McNeil, J.L. Newman, and K.H. Rosenberger. "Performance Objective Demonstration Document (PODD) for the Closure of Tank 19 and Tank 18 Savannah River Site." CBU–PIT–2005–00106. Rev. 1. Westinghouse Savannah River Company. 2005.

Public Law 108-375, "Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005." October 2004.

U.S. Department of Energy (DOE). "Radioactive Waste Management." DOE O 435.1. August 2001a.

———. "Radioactive Waste Management Manual." DOE M 435.1-1. June 2001b.

———. "Draft Section 3116 Determination Salt Waste Disposal Savannah River Site." DOE–WD–2005–001. DOE-Savannah River. March 2005a.

———. "Draft Section 3116 Determination Idaho Nuclear Technology and Engineering Center Tank Farm Facility." DOE/NE–ID–11226. DOE, Idaho Operations Office. 2005b.

———. "Draft Section 3116 Determination for Closure of Tank 19 and Tank 18 at the Savannah River Site." DOE–WD–2005–002. DOE-Savannah River. September 2005c.

U.S. Nuclear Regulatory Commission (NRC). "Draft Environmental Impact Statement on 10 CFR Part 61 Licensing Requirements for Land Disposal of Radioactive Waste." NUREG–0782. Washington, DC. September 1981.

———. "Site Suitability, Selection, and Characterization, Branch Technical Position—Low-Level Waste Licensing Branch." NUREG–0902. April 1982.

———. "Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility." NUREG-1200. January 1988.

———. "A Performance Assessment Methodology for Low-Level Radioactive Waste Disposal Facilities: Recommendations of NRC's Performance Assessment Working Group." NUREG–1573. October 2000.

———. "Decommissioning Criteria for the West Valley Demonstration Project (M–32) at the West Valley Site; Final Policy Statement." *Federal Register*. Vol. 67, No. 22. February 2002.

———. NUREG–1757, "Consolidated NMSS Decommissioning Guidance." Vols. 1–3. September 2003a.

———. "NRC Review of Idaho Nuclear Technology and Engineering Center Draft Waste Incidental to Reprocessing Determination for Tank Farm Facility Residuals - Conclusions and Recommendations." Letter from L. Kokajko to J. Case, DOE. June 2003b.

———. "Technical Evaluation Report for the U.S. Department of Energy, Savannah River Site Draft Section 3116 Waste Determination for Salt Waste Disposal." Letter from L. Camper to C. Anderson, DOE. December 2005.

Rosenberger, K.H., B.C. Rogers, and R.K. Cauthen. “Saltstone Performance Objective Demonstration Document (U).” CBU–PIT–2005–00146. Rev. 0. Westinghouse Savannah River Company. 2005.

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2 INCIDENTAL WASTE CRITERIA

This section of the review plan discusses the criteria against which a waste determination will be reviewed, so that U.S. Nuclear Regulatory Commission (NRC) reviewers understand the criteria and how to evaluate the approaches that the U.S. Department of Energy (DOE) might use to show that the criteria can be met. This section provides information concerning the waste criteria from Section 3116 of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA) (Section 2.1), the DOE Order 435.1 “Radioactive Waste Management” and the associated Manual, “Radioactive Waste Management Manual” (Section 2.2), and the West Valley Policy Statement (Section 2.3). In general, there are several similarities between the different sets of criteria (e.g., all of the sets of criteria include the performance objectives of 10 CFR Part 61, Subpart C) and a few important differences (e.g., not all of the sets of criteria require that certain concentration limits be met). Where appropriate, this review plan applies consistent guidance for reviewing similar criteria. Differences in criteria are discussed in Section 2.4. Sections 2.5-2.7 provide information on reviewing certain criteria, some of which is described in greater detail in Sections 3-7.

2.1 Criteria from the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (Section 3116)

Section 3116 of the NDAA (Public Law 108-375, 2004) (see the appendix) identifies the following criteria for determining that waste is not high-level waste (HLW) and therefore does not require permanent isolation in a deep geologic repository for spent nuclear fuel or HLW:

(1) The waste does not require permanent isolation in a deep geologic repository for spent nuclear fuel or HLW (see Section 2.5);

(2) The waste has had highly radioactive radionuclides removed to the maximum extent practical (see Sections 2.6 and 3); and

(3)A The waste does not exceed concentration limits for Class C low-level waste (LLW) and will be disposed of in compliance with the performance objectives in 10 CFR Part 61, Subpart C (see Sections 2.7 and 3-7); or

(3)B The waste exceeds concentration limits for Class C LLW but will be disposed of in compliance with the performance objectives in 10 CFR Part 61, Subpart C (see Sections 4-7), and pursuant to plans developed by DOE in consultation with NRC (see Sections 2.7 and 3-7).

As described in paragraphs (c) and (d) of Section 3116 of the NDAA, these criteria are applicable to certain waste that will be disposed of in South Carolina and Idaho, and not to waste that will be transported out of those States. The NDAA may not apply to waste that does not meet other criteria in the NDAA (e.g., waste not covered by State-issued closure plans or permits).

2.2 Criteria from DOE Order 435.1

The DOE Order 435.1 and the related Manual 435.1-1 (DOE, 2001a, 2001b) allow for the consideration that incidental waste may be either low-level waste (LLW) or transuranic (TRU) waste, and includes two corresponding sets of similar criteria for determining that waste is incidental to reprocessing.

Incidental wastes that will be managed as LLW will meet the following criteria:

(1) Have been processed, or will be processed, to remove key radionuclides to the maximum extent that is technically and economically practical (see Sections 2.6 and 3);

(2) Will be managed to meet safety requirements comparable to the performance objectives set out in 10 CFR Part 61, Subpart C (see Sections 2.7 and 4-7); and

(3) Are to be managed, pursuant to DOE's authority under the Atomic Energy Act of 1954, as amended, and in accordance with the provisions of Chapter IV of the DOE Radioactive Waste Management Manual (DOE, 2001b), provided the waste will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C LLW as set out in 10 CFR 61.55 (see Section 3.5), or will meet alternative requirements for waste classification and characterization as DOE may authorize;

Incidental wastes that will be managed as transuranic wastes will meet the following criteria:

(1) Have been processed, or will be processed, to remove key radionuclides to the maximum extent that is technically and economically practical (see Sections 2.6 and 3);

(2) Will be incorporated in a solid physical form and meet alternative requirements for waste classification and characteristics, as DOE may authorize; and

(3) Are managed pursuant to DOE's authority under the Atomic Energy Act of 1954, as amended, in accordance with the provisions of Chapter III of the DOE Radioactive Waste Management Manual (DOE, 2001b), as appropriate.

The requirements in DOE Order 435.1 and the associated Manual (DOE, 2001a, 2001b) may be applicable to waste in South Carolina or Idaho that is not covered by the NDAA, waste at Hanford, or waste being shipped off site from West Valley.

The wording in DOE M 435.1-1 does not require that DOE necessarily use the waste classifications in 10 CFR 61.55 or the performance objectives in 10 CFR Part 61, and DOE has the flexibility to use criteria that are different (DOE, 2001b). NRC does not have a regulatory or statutory role with regard to whether the alternate criteria proposed by DOE in a waste determination in accordance with DOE 435.1 are acceptable. Because the alternate criteria that may be proposed by DOE cannot be known at this time, specific associated guidance cannot be provided in this review plan; however, the general approach and review areas identified in the review plan will still provide useful insights to the reviewer. In general, the NRC staff review should assess whether there is reasonable assurance that the proposed alternate criteria can be met, and may provide an independent risk-informed, performance-based assessment of whether the criteria are protective of public health and safety.

In February 2002, the Natural Resources Defense Council (NRDC), Snake River Alliance, and the Yakama and Shoshone-Bannock Nations filed suit against the DOE, stating that the Nuclear Waste Policy Act did not allow DOE to reclassify HLW and dispose of it anywhere except in a geologic repository. In July 2003, the Federal District Court in Idaho granted summary judgment to NRDC and declared DOE's incidental waste process, as described in DOE Order 435.1, invalid. DOE appealed the decision; in November 2004, the U.S. Court of Appeals for the Ninth Circuit vacated the lower court's decision on ripeness grounds.

2.3 Criteria from the West Valley Policy Statement

The NRC's "Decommissioning Criteria for the West Valley Demonstration Project at the West Valley Site; Final Policy Statement" (West Valley Policy Statement) identifies the following criteria for incidental waste determinations (NRC, 2002):

(1) The waste should be processed (or should be further processed) to remove key radionuclides to the maximum extent that is technically and economically practical (see Sections 2.6 and 3); and

(2) The waste should be managed so that safety requirements comparable to the performance objectives in 10 CFR Part 61, Subpart C, are satisfied (see Sections 2.7 and 4-7).

NRC's West Valley Policy Statement provides criteria that are applicable to waste that may be disposed of on site at West Valley.

The West Valley Policy Statement also states that "the resulting calculated dose from incidental waste is to be integrated with all the other calculated doses from the material remaining at the entire NRC-licensed site." However, this review plan covers only the review of incidental waste determinations, not the larger analysis of whether the entire site meets the West Valley Policy Statement or any other applicable requirements.

2.4 Comparison of Criteria

In general, there are several similarities between the different sets of criteria (e.g., all of the sets of criteria include the performance objectives of 10 CFR Part 61, Subpart C) and a few important differences (e.g., not all of the sets of criteria require that certain concentration limits be met). Where appropriate, this review plan applies consistent guidance for reviewing those criteria that are similar, as discussed below.

2.4.1 "Waste Incidental to Reprocessing" and "Non-High-Level Waste"

Historically, the type of waste addressed in waste determinations has been referred to as "waste-incidental-to-reprocessing" (WIR) or "incidental waste," and the waste determinations have been called “WIR determinations.” The NDAA does not use the term “incidental waste” or “WIR” but instead specifies that HLW does not include wastes that meet the criteria of the NDAA; therefore, DOE refers to waste that is covered by the NDAA as “non-HLW” and the associated waste determinations as “non-HLW determinations.” The NRC staff considers WIR, incidental waste, and non-HLW to be the same type of waste; that is, they are wastes that are incidental to the reprocessing of nuclear fuel and can be managed as LLW if the appropriate criteria can be met. This review plan uses the term “incidental waste” to mean both “WIR” and “non-HLW waste,” and uses the term “waste determinations” to mean both “WIR determinations” and “non-HLW determinations.”

2.4.2 “Highly Radioactive Radionuclides” and “Key Radionuclides”

The NDAA refers to “highly radioactive radionuclides” while DOE M 435.1-1 and the West Valley Policy Statement both refer to “key radionuclides.” The NRC staff has previously stated that it believes that “highly radioactive radionuclides” are those radionuclides that contribute most significantly to risk to the public, workers, and the environment (NRC, 2005). This is the same concept as key radionuclides, as used in previous NRC reviews of waste determinations (NRC, 2003). Therefore, for purposes of evaluating waste determinations, the NRC staff considers key radionuclides and highly radioactive radionuclides to be equivalent. For ease of reference, this review plan uses the term “highly radioactive radionuclides” to also mean “key radionuclides.” See Section 3.2 for guidance on evaluating the identification of highly radioactive radionuclides.

2.4.3 “Maximum Extent Practical” and “Maximum Extent Technically and Economically Practical”

The NDAA refers to removal of radionuclides to the “maximum extent practical,” while DOE M 435.1-1 and the West Valley Policy Statement both refer to “the maximum extent technically and economically practical.” The “maximum extent practical” is similar to the “maximum extent technically and economically practical,” but allows for somewhat broader considerations of what is practical (e.g., DOE’s schedule, programmatic considerations, other risk considerations such as worker risk and public risk). However, in most cases, those broader considerations should be evaluated in a quantitative manner; for example, schedule delays could be quantified by estimating the monetary cost or the risk of delaying waste processing. The NRC staff believes that DOE should consider both technological and economic aspects of waste removal in demonstrating compliance with the maximum extent practical criterion. For ease of reference, this review plan will use the term “maximum extent practical” to also mean “maximum extent technically and economically practical.” See Section 3 for guidance on evaluating the removal to the maximum extent practical.

NRC staff believes that, in the case of residual waste that will be stabilized and disposed of in place (e.g., residual waste in tanks), the intent of requiring removal of highly radioactive radionuclides to the maximum extent practical could be met by reducing the volume of the residual waste to the maximum extent practical. However, this general approach of evaluating the physical removal of waste from a piece of equipment or storage container (e.g., a tank) does not eliminate the need to consider whether technologies exist that may be appropriate for removing selected highly radioactive radionuclides from the waste. Therefore, in cases in which DOE plans to remove waste from the disposal system (e.g., by physically removing waste from a tank), reviewers also should consider information about technologies that could be used to remove highly radioactive radionuclides from the waste (e.g., by chemical extraction of radionuclides from waste that will remain in a tank). In general, in this review plan, unless otherwise specified, "removal" of radionuclides refers to removal of waste from a disposal system (e.g., removal of waste from a tank that will be closed in place) as well as treatment to remove radionuclides from a waste stream (e.g. treatment of salt waste at SRS to remove highly radioactive radionuclides prior to disposing of the waste), as applicable.

2.4.4 Differences in Concentration Limits

The NDAA specifies that if the waste being evaluated exceeds the concentration limits for Class C waste, as given in 10 CFR 61.55, DOE is required to consult with NRC on the development of its disposal plans for that waste. Although additional consultation is required, the NDAA does not prohibit waste that exceeds Class C concentration limits from being determined to be incidental waste. Although the NDAA does not specify that the waste must be in solid form, as DOE M 435.1-1 does, NRC generally requires that waste be disposed of in solid form to provide stability (10 CFR 61.56), and the staff believes this is appropriate for waste that is evaluated in compliance with 10 CFR Part 61 stability requirements or comparable requirements.

DOE M 435.1-1 specifies that the waste must be in solid form at a concentration that does not exceed the applicable concentration limits for Class C LLW as set out in 10 CFR 61.55, or that the waste will meet alternative requirements for waste classification and characterization as DOE may authorize. Therefore, DOE M 435.1-1 does prohibit waste that exceeds Class C concentration limits from being determined to be incidental waste unless DOE authorizes alternate criteria. See Section 3.5 for guidance on reviewing the evaluation of the class of the waste. Because any alternate criteria that may be proposed by DOE cannot be known at this time, specific associated guidance cannot be provided in this review plan; however, the general approach and review areas identified in the review plan will still provide useful insights to the reviewer. If DOE does authorize alternate criteria and NRC is reviewing the associated waste determination, the reviewer should evaluate whether there is reasonable assurance that the alternate criteria can be met and whether the proposed alternate criteria are protective of public health and safety.

The West Valley Policy Statement does not include a concentration limit criterion with respect to determining whether waste is incidental.

2.4.5 Alternatives to the Performance Objectives of 10 CFR 61, Subpart C

The NDAA specifies that the "waste....will be disposed of in compliance with the performance objectives in 10 CFR Part 61, Subpart C." DOE M 435.1-1 and the West Valley Policy Statement require that the "waste should be managed so that safety requirements comparable to the performance objectives in 10 CFR Part 61, Subpart C, are satisfied." In other words, the NDAA does not allow for safety requirements that are "comparable" to 10 CFR Part 61, Subpart C, but instead specifies that only Subpart C can be used. For waste determinations made using DOE Order 435.1 and the West Valley Policy Statement, DOE could propose alternate safety requirements, as long as adequate technical basis is provided for determining that the proposed alternate safety requirements are comparable to 10 CFR Part 61, Subpart C. In general, because the requirements in Subpart C are NRC's performance objectives for the disposal of waste in LLW facilities, strong justification for using alternative safety requirements would be required, unless it can be determined that the proposed alternate safety requirements are more stringent than those of 10 CFR Part 61, Subpart C. Because the proposed alternative safety requirements that may be proposed by DOE in the future cannot be known at this time, specific associated guidance cannot be provided in this review plan; however, the general approach and review areas identified in the review plan will provide useful insights to the reviewer. See Sections 4-7 for guidance on reviewing whether there is reasonable assurance that the performance objectives of 10 CFR Part 61, Subpart C, can be met.

2.5 Does Not Require Disposal in a Geologic Repository

The NDAA contains a criterion that the waste does not require permanent isolation in a deep geologic repository for spent fuel or high-level radioactive waste. DOE M 435.1-1 and the West Valley Policy Statement do not contain the same criterion with respect to incidental waste determinations, although disposal in a geologic repository for HLW may be required by other statutes or regulations.

2.5.1 Areas of Review

In general, there is reasonable assurance that this criterion can be met if the two other criteria of the NDAA can be met. In other words, if highly radioactive radionuclides have been removed to the maximum extent practical and the waste will be disposed of in compliance with the performance objectives in 10 CFR Part 61, Subpart C (which are the same performance objectives NRC uses for disposal of low-level waste), then this supports a conclusion that the waste does not require disposal in a deep geologic repository. However, this criterion allows for the consideration that waste may require disposal in a geologic repository even though the two other criteria of the NDAA may be met. Consideration could be given to those circumstances under which geologic disposal is warranted in order to protect public health and safety and the environment; for example, unique radiological characteristics of waste or non-proliferation concerns for particular types of material (NRC, 2005).

2.5.2 Review Procedures

The review should determine the following:

- If there is reasonable assurance that the other criteria of the NDAA can be met (see Sections 2-8); and

- That no other characteristics of the waste would require that the waste be disposed of in a deep geologic repository in order to protect public health and safety.

2.6 Removal of Radionuclides

Each of the sets of criteria governing waste determinations contain a requirement that certain radionuclides be removed to the maximum extent practical. As discussed in Sections 2.4.2 and 2.4.3, there are differences between the radionuclide removal requirements of the NDAA, DOE Order 435.1, and the West Valley Policy Statement. Criterion 2 of the NDAA requires that highly radioactive radionuclides be removed to the maximum extent practical. DOE M 435.1-1

(DOE, 2001b) and the West Valley Policy Statement (NRC, 2002) require that key radionuclides be removed to the maximum extent that is technically and economically practical. As discussed in Section 2.4.3, NRC staff believes that NDAA wording provides more flexibility in demonstrating compliance with this criterion. See Section 3 for detailed guidance on determining whether this criterion has been met.

2.7 Compliance With Performance Objectives of 10 CFR Part 61, Subpart C

As discussed in Section 2.4.5, there are differences between the NDAA, DOE M 435.1-1, and the West Valley Policy Statement requirements regarding the performance objectives of 10 CFR Part 61. In most cases, it is expected that the reviewer should evaluate compliance with the performance objectives in 10 CFR Part 61, Subpart C.

The general requirement of 61.40 requires that land disposal facilities be sited, designed, operated, closed, and controlled after closure so that reasonable assurance exists that exposures to humans are within the limits established in the performance objectives in 10 CFR 61.41-61.44. The reviewer should evaluate compliance with this requirement by performing the reviews described in Sections 4-7 of this review plan.

To evaluate compliance with the performance objective for the protection of the general population from releases of radioactivity (10 CFR 61.41) the reviewer should confirm that concentrations of radioactive material which may be released to the general environment in groundwater, surface water, air, soil, plants, or animals will not result in an annual dose to a member of the public that is greater than 0.25 mSv (25 mrem), and will be maintained as low as is reasonably achievable (ALARA). The reviewer should evaluate compliance with this requirement as described in Section 4 of this review plan. Note that, although 10 CFR 61.41 requires that materials released to the general environment will not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public, the NRC staff uses an exposure limit of 0.25 mSv (25 mrem) total effective dose equivalent (TEDE) in making this assessment (NRC, 1999, 2005).

The performance objective for protection of individuals from inadvertent intrusion (10 CFR 61.42) requires that the design, operation, and closure of the land disposal facility will ensure protection of any individual inadvertently intruding into the disposal site and occupying the site, or contacting the waste at any time after active institutional controls over the disposal site are removed. The performance objective does not provide numerical dose criteria for protection from the inadvertent intruder. However, NRC typically applies a whole body-dose equivalent limit of 5 mSv/yr (500 mrem/yr), as described in the Draft Environmental Impact Statement for 10 CFR Part 61 (NRC, 1981) to assess compliance with 10 CFR 61.42. The reviewer should evaluate compliance with this requirement as described in Section 5 of this review plan.

The performance objective for the protection of individuals during operations (10 CFR 61.43) requires that operations at the land disposal facility will be conducted in compliance with the standards for radiation protection set out in 10 CFR Part 20, except for releases of radioactivity in effluents from the land disposal facility, which will be governed by 10 CFR 61.41. In addition, the performance objective requires that radiation exposures during operations are maintained

ALARA. The information reviewed using Section 6 of this review plan supports the evaluation of compliance with this requirement.

The performance objective for stability of the disposal site after closure (10 CFR 61.44) requires that a disposal facility be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate, to the extent practicable, the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care is required. Evaluation of compliance with 10 CFR 61.44 is limited to a review of site stability, as described in Section 7. However, because the stability of a disposal site is important to its long term performance, the reviewer should ensure that the effects of site instabilities identified in this part of the review are adequately modeled or bounded in the performance assessment (see Section 4) and inadvertent intruder analysis (see Section 5).

2.8 References

Public Law 108-375, "Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005." October 2004.

U.S. Department of Energy (DOE). "Radioactive Waste Management." DOE O 435.1. 2001a.

———. "Radioactive Waste Management Manual." DOE M 435.1-1. 2001b.

U.S. Nuclear Regulatory Commission (NRC). "Draft Environmental Impact Statement on 10 CFR Part 61, Licensing Requirements for Land Disposal of Radioactive Waste." NUREG–0782. September 1981.

———. "Disposal of High-Level Radioactive Wastes in a Proposed Geological Repository at Yucca Mountain, Nevada." Proposed Rule. *Federal Register.* 64 FR 8640. February 1999.

———. "Decommissioning Criteria for the West Valley Demonstration Project (M–32) at the West Valley Site; Final Policy Statement." *Federal Register.* 67 FR 5003. February 2002.

———. "NRC Review of Idaho Nuclear Technology and Engineering Center Draft Waste Incidental to Reprocessing Determination for Tank Farm Facility Residuals - Conclusions and Recommendations." Letter from L. Kokajko to J. Case, DOE. June 2003.

———. "Technical Evaluation Report for the U.S. Department of Energy, Savannah River Site Draft Section 3116 Waste Determination for Salt Waste Disposal." Letter from L. Camper to C. Anderson, DOE. December 2005.

3 RADIONUCLIDE REMOVAL AND CONCENTRATION LIMITS

As discussed in Sections 2.4.2 and 2.4.3, each set of incidental waste criteria contains a requirement that highly radioactive radionuclides be removed to the maximum extent practical. Because relevant wastes may have a wide range of physical, chemical, and radiological characteristics, the list of highly radioactive radionuclides is expected to vary among different waste determinations. In general, NRC staff believes that highly radioactive radionuclides are those radionuclides that contribute most significantly to risk to the public, workers, and the environment (NRC, 2005).

Depending on the circumstance, the removal of radionuclides may refer to the minimization of the volume of residual waste remaining in place (e.g., removal of waste from a tank that is to be closed) or to the removal of radionuclides from a waste stream (e.g., removal of radionuclides from salt waste being disposed of as saltstone at SRS). Essentially, the common goal of the various radionuclide removal criteria is to ensure that DOE minimizes inventory of highly radioactive radionuclides in wastes that are classified as incidental.

The evaluation of compliance with each of the radionuclide removal criteria generally involves three steps:

- Evaluate the waste inventory, including sampling, analysis, calculations, and uncertainties that may affect estimates of waste volumes and radionuclide concentrations.

- Evaluate DOE's basis for selecting highly radioactive radionuclides.

- Evaluate the technical basis for determining whether radionuclides have been (or will be) removed to the maximum extent practical, including evaluations of the waste removal technologies selected by DOE, the process used to determine that waste removal has been (or will be) completed, and costs and benefits of additional waste removal.

This section provides review areas and procedures for each of these steps. In addition to the radionuclide removal criterion of the West Valley Policy Statement, radionuclide removal activities at the West Valley site may be subject to separate analyses to support NRC license modification or termination under the West Valley Policy Statement (see Section 2.3). Analyses to support NRC license modification or termination at West Valley will be performed independently of the waste determination process, and these analyses are not addressed in this review plan.

As discussed in Section 2.4.4, the NDAA and DOE M 435.1-1 require that wastes be classified as a function of radionuclide concentrations; the NDAA requires classification according to the concentration limits described in 10 CFR 61.55, while DOE Order 435.1 allows classification either by the concentration limits described in 10 CFR 61.55 or by alternate requirements as authorized by DOE. Because the assessment of radionuclide concentrations is part of the assessment of radionuclide inventory, and is essential to waste classification, this section also addresses the review of compliance with the NDAA and DOE M 435.1-1 requirements related to radionuclide concentrations and waste classification.

3.1 Inventory of Radionuclides in Waste

Evaluating the inventory of radionuclides in the waste is the first step in identifying highly radioactive radionuclides and evaluating the extent to which they can be removed. Radionuclide inventories also are needed to develop a source term model for a performance assessment and inadvertent intruder analysis (see Section 4.3.3.1.3).

3.1.1 Areas of Review

The reviewer should evaluate the description of the radionuclide inventory in the waste, including radionuclide activities and waste volumes. Radionuclides with relatively high solubility, low sorption, high dose conversion factors, and/or significant ingrowth are of particular significance.

The reviewer should evaluate the history of the wastes of interest, including information about the generation of the waste streams identified in the waste determination and any treatment processes (e.g., neutralization of acidic waste) that could influence the physical, chemical, or radiological characteristics of the waste. The reviewer also should evaluate previous inventory estimates and the reasons for any differences between the previous estimates and estimates provided in the waste determination.

The reviewer should evaluate the sampling methodologies used to determine radionuclide activities, including the rationale for the sampling approach, the particular sampling points chosen, and the justification for the number of samples collected. The reviewer should evaluate the spatial distribution of the radionuclides within the waste, including, if appropriate, both the areal and vertical distribution of radionuclides. The reviewer should ensure that the sampling methodology appropriately accounted for the heterogeneity of the waste. In assessing the representativeness of samples, the reviewer should consider any reasons why wastes of different composition may not have been adequately sampled (e.g., if the range of sample depths in a tank is limited and wastes of different composition may have stratified). The reviewer should evaluate the potential effects of access limitations (e.g., waste inside of abandoned equipment or in sand pads, limited available risers or limited possibilities to create new sampling ports in the tops of tanks) in limiting sample locations. In addition to evaluating uncertainties due to sample variability (e.g., quantified as the variability among sample measurements), the reviewer should evaluate additional uncertainties in radionuclide activities that would result if the samples do not adequately represent waste heterogeneity. In assessing waste heterogeneity, the reviewer should consider information about activities performed to mix the waste and about any areas that may have remained unmixed.

The reviewer should evaluate the analytical methodologies used to characterize the radionuclide inventory of the waste, including information about the calibration and sensitivity of the instruments used to make the measurements. Any assumptions made and reported uncertainties should be reviewed as well. The reviewer should evaluate the expected impact of analytic uncertainty as compared to the uncertainties due to sample variability.

DOE may estimate concentrations of radionuclides that were not measured. Inventory estimates may be based on historical knowledge (e.g., tracking of waste added to tanks) or other types of process knowledge (e.g., waste treatment efficiencies or ORIGEN2 calculations based on cladding and fuel types, burnup levels, cooling times, and other parameters). The reviewer should evaluate parameter values and assumptions used in making these estimates. The applicability of process knowledge estimates to the waste conditions (e.g., the applicability of ORIGEN2 calculations to estimate radionuclide inventories in tanks in which radionuclides may have been removed to different extents because of association with different physical phases) should be evaluated. In general, inventory estimates based on historical or process knowledge and special calculations are expected to be more uncertain than estimates based on sample measurements, and the reviewer should evaluate the technical basis for uncertainties in the estimated values or the technical basis for concluding that the estimated values are conservative. If possible, the reviewer should compare the results of similar calculations made before sampling with sampled values of chemically similar radionuclides to evaluate the expected reliability of the calculated estimates.

The reviewer should examine the methods used to determine the volume of waste used in inventory calculations (e.g., use of geostatistical methods to calculate waste volumes based on camera recordings of waste in tanks) and evaluate reported uncertainties in waste volumes. The reviewer should evaluate the expected impact of volume uncertainties as compared to the uncertainties in radionuclide concentrations due to sample variability.

3.1.2 Review Procedures

Radionuclide inventories are used to support the evaluation of the removal of highly radioactive radionuclides as well as to support the development of a source term model (see Section 4.3.3.1.3). In general, reviewers should evaluate information about waste history, sampling, measured radionuclide activities, waste volumes, and any calculations performed to estimate radionuclide inventories, as well as the technical bases for the resulting radionuclide inventory estimates. It is particularly important for reviewers to evaluate the technical bases for uncertainties associated with sample heterogeneity or estimates based on historical or process knowledge, and to determine whether uncertainties in radionuclide inventories have been adequately represented or bounded. Specifically, the reviewer should perform the following activities:

- Evaluate information about waste generation and treatment activities and determine whether the reported radionuclide concentrations appear to be consistent with expected concentrations in contributing waste streams. For example, much lower concentrations of fission products (e.g., Sr-90, Tc-99, Cs-137) and elements used in fuel cladding (e.g., Zr, Al) would be expected in tanks receiving primarily second- or third-cycle wastes as compared to tanks receiving primarily first-cycle extraction waste.

- Verify that the predicted physical and chemical forms of radionuclides are consistent with the properties of contributing waste streams and previous waste management activities (e.g., precipitation of radionuclides during neutralization of acidic waste, partitioning of radionuclides onto zeolites).

- Evaluate previous inventory estimates and verify that the technical bases for any differences between historical and current estimates are adequate.

- Determine whether waste samples adequately represent heterogeneity of the waste. Specifically evaluate the number, location, depth, and physical phases of samples as well as the expected degree of mixing of the waste. Identify any unsampled wastes (e.g., wastes in abandoned equipment in tanks, waste in unsampled hardened mounds) and determine if the unsampled wastes may contribute significant uncertainty to total radionuclide inventories. Verify that uncertainties resulting from waste heterogeneity are adequately represented or bounded in the reported radionuclide inventories.

- If applicable, evaluate sampling and analysis plans, and data quality assessments, and verify that relevant data quality objectives are met. If the data quality objectives are not met, then the reviewer should evaluate DOE's technical basis for concluding that the data are sufficient to support the inventory estimates (e.g., a comparison of sampling results to previous sampling results that met data quality objectives or predictions based on other techniques).

- Verify that estimates of the number of required samples provided in the sampling plan are based on accurate assumptions about the heterogeneity of the waste. For example, verify that calculations of the number of samples needed to provide the desired statistical power or upper confidence limits are not based on the assumption that the waste is well-mixed if it is not well-mixed.

- Assess the technical basis for any identified limitations in the number or locations of samples (e.g., limited number of sampling ports or internal obstructions in tanks, difficulties in sampling specific phases of waste, significant worker hazards) and confirm that the resulting uncertainties in total inventory have been adequately represented or bounded.

- Evaluate the analytical methods used to measure radionuclide concentrations and verify that the analytical techniques used have the appropriate sensitivity for the radionuclides of interest, and the uncertainties in the analytical methods (e.g., due to instrument calibration) are either propagated into the inventory estimates or have been adequately bounded.

- Verify that DOE has adequately described sampling and analytical uncertainties, and properly identified the uncertainty propagated into calculations of waste inventory (e.g., ensure that analytic uncertainty is not substituted for sample variability).

- Evaluate the statistical metric of radionuclide concentrations used to calculate inventories in the waste determination (e.g., mean, 95% upper confidence limit) to ensure that the technical basis for the selection is adequate, and the metric is properly calculated.

- Evaluate methods used to estimate the inventory of highly radioactive radionuclides, and determine whether reasonable efforts have been made to base concentrations for highly radioactive nuclides on sample measurements. If the concentrations of highly radioactive nuclides are based on calculations or process knowledge, verify that the technical justification for using calculated rather than sampled values is adequate (e.g., lack of analytical techniques with appropriate detection limits).

- Verify that if techniques other than site-specific measurements are used to estimate radionuclide concentrations (e.g., estimates based on historical knowledge or ORIGEN2 calculations), that the techniques have been appropriately verified and validated. For example, the reviewer should compare any estimates made prior to sampling with sampled values and verify that the estimated values were accurate or conservative, or that the reasons for any non-conservative estimates are understood. The reviewer should ensure that comparisons of predicted and measured values provide an adequate basis for the reliability of estimates of chemically similar radionuclides that have not been sampled.

- If estimates are based on historical data (e.g., tracking of wastes added to a waste tank) or process knowledge, ensure that significant sources of uncertainty (e.g., waste stream variability, unknown waste streams) have been adequately characterized and propagated in inventory estimates.

- If estimates are based on process knowledge (e.g., ORIGEN2 calculations), verify that the effects of subsequent waste management activities (e.g., precipitation of radionuclides during neutralization of acidic waste and subsequent incongruent removal of waste phases) are included appropriately in inventory estimates.

- Confirm that DOE has an adequate technical basis for estimating the volume of the waste. Evaluate the methods (e.g., geometry, models, statistical techniques) used for estimating waste volumes, and confirm that uncertainty has been considered and propagated into the inventory estimate. For example, if DOE uses geostatistical methods to estimate tank waste residual volumes after radionuclide removal, the uncertainty should be adequately reflected in the analysis.

3.2 Identification of Highly Radioactive Radionuclides

As discussed in Section 2.4.2, the NRC staff believes that highly radioactive radionuclides are those radionuclides that contribute most significantly to risk to the public, workers, and the environment (NRC, 2005). Because highly radioactive radionuclides are defined in terms of the risk they pose to various receptors, the identification of highly radioactive radionuclides is sensitive to changes made in the performance assessment, inadvertent intruder analysis, and calculations of worker risk. Therefore, the choice of highly radioactive radionuclides should be sufficiently conservative so that all potential highly radionuclides are included, or the selection process should be iterative so that a radionuclide is added to the list if changes in the relevant risk calculations increase the predicted risk significance of the radionuclide.

A list of highly radioactive radionuclides is expected to be specific to a particular waste determination, and radionuclides that are identified as highly radioactive radionuclides in one waste determination are not necessarily expected to be identified as highly radioactive radionuclides in another waste determination.

3.2.1 Areas of Review

Because highly radioactive radionuclides are defined in terms of the risks they pose to various receptors (see Section 2.4.2), the selected highly radioactive radionuclides ultimately must be compared to the results of risk calculations. In general, the reviewer should evaluate the contribution of radionuclides present in the waste to radiological dose to members of the general public (including inadvertent intruders) and workers. The most important contributors to dose are expected to be identified as highly radioactive radionuclides even if the absolute magnitude of the predicted doses is low. Although radionuclides with low predicted doses may be identified as highly radioactive radionuclides, the magnitude of the predicted doses will affect the analysis of the removal to the maximum extent practical (see Section 3.4). In reviewing the identification of highly radioactive radionuclides, it is particularly important that the reviewer evaluate the potential uncertainties in predicted receptor doses. Potential contributions to uncertainties in performance assessment and inadvertent intruder results are discussed in Sections 4 and 5, respectively. In identifying uncertainties, the reviewer should consider the results of independent performance assessment and inadvertent intruder analyses.

DOE may present the identification of highly radioactive radionuclides by starting with radionuclide inventories and eliminating radionuclides from the list of potential highly radioactive radionuclides based on screening criteria. In these cases, the reviewer should pay particular attention to uncertainties in radionuclide inventories (see Section 3.1) and assess the reasonableness of any screening criteria used to remove radionuclides from the list of potential highly radioactive radionuclides.

3.2.2 Review Procedures

The reviewer should ensure that initial identification of highly radioactive radionuclides is sufficiently conservative that it does not omit radionuclides that may be predicted to cause a significant contribution to risk after uncertainties in risk calculations are resolved. The reviewer should then evaluate any iterative analysis that may be used to refine the initial list, identify those radionuclides that contribute most to dose, and identify those uncertainties that are expected to have the most significant impact on predicted dose. Specifically, the reviewer should perform the following review procedures.

- If a screening analysis is used, the reviewer should perform the following activities:

  - Ensure that the initial list of radionuclides included in the analysis is comprehensive;

  - Evaluate screening criteria used by DOE to eliminate potential highly radioactive radionuclides (e.g., short half-life, low total activity in the waste), and verify that they are reasonable and sufficiently conservative; and

  - Ensure that ingrowth of daughters is considered and that parent radionuclides are not inappropriately screened from analysis.

- Verify that DOE has considered the appropriate receptors (i.e., workers and members of the public including inadvertent intruders) in defining its list of highly radioactive radionuclides.

- Ensure that uncertainties in radionuclide inventories are adequately represented in initial lists of radionuclides used in screening procedures (see Section 3.1).

- Ensure that uncertainties in performance assessment and inadvertent intruder analyses are adequately represented in the selection of highly radioactive radionuclides (see Sections 4 and 5).

- Use independent analyses to assess which radionuclides are expected to cause the most significant risk to members of the public, including the inadvertent intruders. Vary model parameters and assumptions to evaluate a reasonable range of alternative scenarios (e.g., regarding barrier performance, biointrusion, flooding, or seismic events). Examine the reasons for any differences between DOE's list of highly radioactive radionuclides and the radionuclides identified as causing significant risk in the independent analyses, and request additional technical basis supporting the DOE analysis, as necessary.

3.3 Removal of Highly Radioactive Radionuclides to the Maximum Extent Practical

As discussed in Section 2.4.3, "removal" of radionuclides refers to both removal of waste from a disposal system and treatment of waste to remove radionuclides from the waste stream. As discussed in Sections 2.4.2 and 2.4.3 , there are differences between the NDAA, DOE Order 435.1 (DOE, 2001), and the West Valley Policy Statement (NRC, 2002) requirements regarding the extent of removal of radionuclides, and the NRC staff believes the NDAA wording allows for broader considerations in demonstrating compliance with this criterion. Typically, however, reviewers should expect to evaluate a quantitative analysis that demonstrates that radionuclides have been removed to the maximum extent practical. For example, impacts of additional removal activities on removal schedules may be related to cost or worker risk.

Because DOE may submit a waste determination either before (DOE, 2005a) or after (DOE, 2005b) it has stopped relevant removal operations, evaluation of compliance with the radionuclide removal criterion may be based on either the extent of removal that has occurred, or the removal that DOE specifies will occur before final disposal actions are taken. Thus, the reviewer may conclude either that highly radioactive radionuclides "have been" or "will be" removed to the maximum extent practical. If DOE submits a waste determination prior to ending removal actions, NRC staff will expect to monitor the extent of radionuclide removal achieved and assess any impacts on meeting the performance objectives of 10 CFR Part 61 Subpart C (Section 10). If removal activities are not completed as described in DOE's waste determination, conclusions regarding radionuclide removal to the maximum extent practical that were made by NRC staff based on the review of the waste determination may no longer be applicable. In general, in this document, unless a distinction is otherwise made, the conclusion that highly radioactive radionuclides "have been" removed to the maximum extent practical should be understood to include cases in which the NRC staff determines that highly radioactive radionuclides "will be" removed to the maximum extent practical based on the removal criteria established by DOE in its waste determination.

3.3.1 Areas of Review

As discussed in Section 2.4.3, it is expected that an NRC reviewer will evaluate both technical and economic aspects of radionuclide removal. In general, review of the technical aspects of radionuclide removal is expected to include an assessment of the technologies DOE selected to perform radionuclide removal, while review of the economics of additional removal is expected to include an assessment of the costs and benefits of additional radionuclide removal. Although reviews of technology selection and cost-benefit analyses are expected to be performed for each waste determination review, some components of the review may depend on the timing of the submission of the waste determination with respect to the status of removal actions. Specifically, if DOE stops relevant removal operations before submitting a waste determination, the review should include an evaluation of the removal actions that have occurred and the decision to stop removal activities, while reviews of waste determinations submitted prior to stopping radionuclide removal operations should include an evaluation of the criteria DOE establishes to determine when removal is complete.

In reviewing the selection of radionuclide removal technologies, the reviewer should evaluate the decision process DOE used to select appropriate technologies as well as the final technology selections. Reviewers should evaluate the range of technologies considered by DOE, the sources of information DOE used (e.g., expert judgement, reports on the status of various technologies, information from other DOE sites), and how information was used in DOE's technology selection process. In assessing removal actions that have been stopped, the reviewer should evaluate the selection process based on the information and technologies available at the time of selection. In assessing the practicality of additional radionuclide removal, the reviewer should assess technologies available at the time of the review. Information about available technologies may be found in reports from other DOE sites as well as reports from third parties (e.g., the National Academy of Sciences [NAS] or Defense Nuclear Facilities Safety Board [DNFSB]). Technologies that have been used successfully at other sites are of particular interest. Reviewers should evaluate DOE's rationale for selection of waste removal techniques, including a comparative assessment of the technical and economic characteristics of the techniques considered.

The NRC staff believes that, in the case of residual waste that will be stabilized and disposed of in place (e.g., residual waste in tanks), the intent of requiring removal of highly radioactive radionuclides to the maximum extent practical could be met by reducing the volume of the residual waste to the maximum extent practical. However, this general approach of evaluating the physical removal of waste from a piece of equipment or storage container (e.g., a tank) does not eliminate the need to consider whether technologies exist that may be appropriate for removing selected highly radioactive radionuclides from the waste. Therefore, in cases in which DOE plans to remove waste from a system that will be closed in place (e.g., by physically removing waste from a tank), reviewers also should consider information about technologies that could be used to remove highly radioactive radionuclides from the waste (e.g., by chemical extraction of radionuclides from waste that will remain in a tank).

To the extent practical, reviewers should consider the impacts of the proposed waste management activities and alternative waste management activities on the broader waste management system. For example, if the generation of additional liquid waste that must be stored in tanks is identified as a significant technical challenge because of limitations on tank space, reviewers should consider whether alternate technologies would generate less secondary liquid waste than the proposed technologies (e.g., by recycling liquids rather than necessitating the use of clean water). Reviewers also should consider the composition of waste streams that could be generated by proposed and alternate radionuclide removal techniques (e.g., effects of oxalic acid on downstream processes).

If relevant removal operations were stopped prior to submission of a waste determination, in addition to reviewing DOE's technology selection process, reviewers should evaluate the technical basis for stopping removal activities. For example, if DOE indicates that waste removal was stopped because of equipment failure, the reviewer should investigate the costs and other impacts (e.g., on schedule) of replacing the failed equipment. Similarly, if limited access to the waste (e.g., due to blocked risers or internal obstructions in a tank) is provided as a reason why additional removal is not practical, the reviewer should investigate the costs and technical challenges associated with modifying the system to improve access (e.g., by removing failed equipment to regain access to a riser or cutting new access ports in the top of a tank). In general, if schedule constraints are identified as a reason why waste removal actions are stopped or why additional removal actions cannot be completed, reviewers should assess the implications of the identified schedule impacts on more quantitative metrics such as cost or worker risk. In assessing the basis for stopping removal activities, the reviewer also should evaluate available documentation of removal goals that were established before radionuclide removal waste started. The reviewer should evaluate both the technical basis for the original removal goal and the consistency of the removal achieved with the removal goal. The actual extent of removal achieved in terms of radionuclide inventories and the uncertainties in those inventories should be reviewed as described in Section 3.1.

If a waste determination is submitted prior to completion (or commencement) of waste removal activities, the reviewer should evaluate DOE's criteria for determining when waste removal is complete. Essentially, a reviewer should evaluate the technical basis for concluding DOE will meet its removal goals and the practicality of achieving a greater extent of radionuclide removal than required by the completion criteria proposed by DOE. For example, if DOE proposes that removal will be complete if a certain volume of waste has been removed from a tank, the reviewer should evaluate DOE's technical basis for concluding the specified volume of waste will be removed and the practicality of removing a substantially greater volume of waste from the tank. Similarly, if DOE proposes to remove radionuclides from a waste stream with a chemical treatment process, the reviewer should evaluate the technical basis for the predicted removal efficiencies as well as the practicality of accomplishing additional radionuclide removal (e.g., by increasing treatment efficiencies).

For removal activities that have not been completed, the reviewer also should identify the main factors that could cause changes in the proposed approach. For example, a technology that is less mature may introduce greater uncertainty in the extent of radionuclide removal that can be accomplished or the cost of the proposed waste management activities. To assess technological maturity, the reviewer should assess information about technologies that have been used or developed at other DOE sites as well as reports from third parties (e.g., NAS or DNFSB). If DOE proposes to use a technology that has not yet been used successfully under similar situations, the reviewer should evaluate DOE's plans for changing the waste management approach to accommodate unforseen problems (e.g., DOE's plans for using alternate technologies to complete radionuclide removal if the originally selected technology cannot achieve the removal goals). Additional uncertainties in the conclusion that radionuclides will be removed to the maximum extent practical may result if radionuclide removal plans extend over long time periods or if removal activities are not expected to begin for a significant amount of time after a waste determination is submitted (e.g., greater than five years) because it may be difficult to conclude that the proposed radionuclide removal activities will remain practical in the future (e.g., because of changing programmatic goals). If waste treatment activities are expected to begin several years after the waste determination has been submitted, the reviewer should evaluate DOE's process for considering technological developments that occur after the submission of the waste determination. In addition, reviewers must consider uncertainties in proposed waste treatment schedules when evaluating the costs and benefits of a particular treatment approach, because changes in the schedule could have a significant effect on the relative costs of various treatment alternatives.

The primary benefit of radionuclide removal is expected to be a reduction in the risk the waste will pose to the general public, including inadvertent intruders. Because the performance assessment and inadvertent intruder analysis provide the basis for quantifying the risk the waste will pose to members of the public, any analysis of the costs and benefits of additional radionuclide removal is expected to depend in part on the performance assessment and inadvertent intruder analysis dose predictions. In addition, radionuclide removal may impact the risk to individuals during operations (see Section 6) or site stability (see Section 7). Therefore, the reviewer should evaluate the consistency of information presented in a cost-benefit analysis to support conclusions about the practicality of additional radionuclide removal with information reviewed using Sections 4-7 of this review plan. For example, if additional removal would require changes to the physical or chemical form of the waste, any impacts on site stability should be evaluated. Similarly, if it is stated that additional removal would cause unacceptable worker risks, the consistency of the predicted worker risks due to additional radionuclide removal with the information presented regarding protection of workers during operations should be evaluated. Furthermore, if changes to the performance assessment or inadvertent intruder analysis are made during the review process, the reviewer should evaluate potential impacts on any cost-benefit analysis used to support the conclusion that highly radioactive radionuclides have been removed to the maximum extent practical. Additional information about reviewing cost-benefit analyses is provided in Section 3.4.

3.3.2 Review Procedures

Reviewers should evaluate waste management activities that have been performed or proposed by DOE as described in the waste determination in comparison to alternate waste management activities. In addition, reviewers should evaluate the technological feasibility and practicality of additional removal of radionuclides. Specifically, the reviewer should perform the following assessments:

- Review DOE's basis for radionuclide removal technology selection. Determine whether a reasonable range of potential technologies was evaluated by comparing the list of technologies considered to technologies used or developed at other DOE sites and by reviewing relevant documents by other organizations, if available (e.g., NAS, DNFSB). Technologies considered should include, but not necessarily be limited to, sluicing (e.g., see [Schlahta and Brouns, 1998]), mixing (e.g., see [Leishear, 2004; Hatchell et al, 2001]), chemical cleaning (e.g., see [Sams, 2004]), vacuum retrieval techniques (e.g., see [Sams, 2004]), mechanical manipulators (e.g, see [DOE, 1998; Evans, 1997]), and robotic vehicles (e.g., see [Vesco et al., 2001]).

- If appropriate, determine whether both methods to remove waste from the disposal system (e.g., removing waste from tanks) and methods to remove radionuclides from relevant waste streams (e.g., chemically extracting radionuclides from waste that will remain in a tank) have been considered.

- Review DOE’s documentation of its process for selecting radionuclide removal technologies, and determine whether the selection process was based on appropriate sources of information that were reasonably current at the time the technology selections were made (e.g., expert elicitation, reports from other DOE sites).

- Determine whether the criteria used by DOE to select radionuclide removal technologies are reasonable. In general, reviewers should expect that selection criteria include an estimate of the likelihood of achieving removal goals with the selected technology, the technological uncertainties associated with each technology (e.g., technological maturity), the costs of implementing the technology, and an evaluation of the system-wide impacts of using the technology (e.g., chemical effects on downstream systems, generation of secondary waste streams requiring storage).

- If waste treatment activities are expected to begin several years after the waste determination has been submitted, the reviewer should evaluate DOE’s process for considering technological developments that occur after the submission of the waste determination. The reviewer should determine whether the process will require evaluation of an appropriate range of alternative technologies (e.g., technologies developed at different DOE sites) and will allow DOE to assess whether it would be practical to improve radionuclide removal by implementing a technology that was developed or improved after submission of the waste determination.

- Examine DOE’s documentation of radionuclide removal activities that have been stopped and verify that key reasons used to support the termination of removal operations (e.g., availability of equipment, changes in equipment performance, programmatic considerations) were reasonable. For example, if deterioration of equipment was cited as a primary reason why waste removal was stopped, efforts to replace failing equipment or improve equipment performance should be investigated. The reviewer should determine whether decisions to stop waste removal activities based on programmatic or schedule constraints can be supported by an evaluation of the costs and potential benefits of continuing removal operations.

- If predicted doses to members of the public (including inadvertent intruders) were used to support the decision to stop radionuclide removal activities, determine whether uncertainties in the dose estimates would have a significant effect on the metrics used to support the decision to stop removal (e.g., cost per averted dose).

- Identify any removal goals established by DOE before radionuclide removal began, and determine whether the goals have been met. If the goals have been met, evaluate the technical basis for the goals and determine whether the goals were consistent with radionuclide removal to the maximum extent practical (i.e., determine whether significantly more radionuclide removal than required by the removal goals would have been practical).

- If removal goals identified by DOE prior to radionuclide removal efforts have not been met, determine whether the technical basis for stopping removal prior to achieving the removal goals is adequate. For example, if technological limitations are cited as the reason why the goals were not met, the reviewer should determine why waste removal was more difficult than originally predicted (e.g., because of poor equipment performance or unforseen characteristics of the waste).

- Verify that reported removal efficiencies of removal operations which have been performed are reasonably reliable. For example, removal of waste from tanks may be quantified by measuring activity as it is removed with detectors outside of piping, by mapping and sampling of residual tank heels, or by other means. The efficiency of treatment methods use to remove radionuclides from a waste may be based on pre- and post-treatment sample measurements or other operational experience.

- Determine what baseline was used to calculate reported removal efficiencies. For example, with respect to removal of waste from tanks, determine whether starting inventories were based on the historical maximum radionuclide inventories, inventories after bulk removal, or another baseline inventory. Verify that any waste added to the tank after the time of the baseline inventory was properly accounted for. Verify that DOE has provided sufficient information to estimate the effectiveness of relevant radionuclide removal technologies (i.e., pre- and post-cleaning inventories).

- For removal operations that have not been completed, verify that DOE's proposed criteria for terminating removal operations include minimum standards that are consistent with meeting the performance objectives. For example, if removal of tank waste is to be considered complete when the removal rate decreases to a certain value, the reviewer should ensure that the criteria also contain minimum removal amounts such that the inventories of highly radioactive radionuclides left in the tank (including uncertainties), will be consistent with or less than the source term used in the performance assessment and inadvertent intruder analysis (see Section 4.3.3.1.3). In general, meeting the performance objectives is necessary, but demonstrating that the performance objectives will be met is not necessarily sufficient to demonstrate that radionuclides will be removed to the maximum extent practical.

- For removal operations that have not been completed, examine DOE's criteria for terminating removal operations and determine whether additional removal would be practical. For example, if removal of waste in a tank is to be considered complete when the removal rate drops to a certain value, determine whether continuing operation would be expected to result in a cost-effective reduction in dose to a member of the public (see Section 3.4).

- For removal operations that have not been completed, verify that predicted removal efficiencies for proposed removal operations are supported by a sufficient technical basis. For example, if waste will be treated by sorption of radionuclides onto a finely dispersed solid and subsequent filtration of that solid from the liquid waste, the reviewer should determine whether the reported predicted efficiencies of sorption and filtration are consistent with efficiencies observed during laboratory or pilot-scale tests under similar conditions, or similar experience at DOE sites.

- To evaluate the practicality of additional radionuclide removal, confirm that DOE technology selections are based on an updated assessment of the state of available technologies. Confirm that DOE has considered new technologies developed across the DOE complex that could be used to achieve additional radionuclide removal.

- Identify technological challenges described by DOE to be limiting factors in the removal of radionuclides. If a stated technological challenge is expected to recur in subsequent removal activities (e.g., if a waste with problematic physical characteristics is present in other tanks at the site), determine what efforts are being made to resolve the challenges and note the challenge and DOE efforts to resolve it in documenting the review of radionuclide removal (see Section 9).

- Review any cost-benefit analysis used to support the decision that additional radionuclide removal would not be practical (see Section 3.4) and confirm that the analysis supports the conclusion that highly radioactive radionuclides have been removed to the maximum extent practical.

3.4 Cost-Benefit Analysis

One part of the evaluation of the removal of highly radionuclides to the maximum extent practical is an evaluation of the costs of designing and implementing various waste management strategies and using various treatment technologies, as well as the resulting benefits in terms of public health and safety. If radionuclide removal activities have ended prior to submission of a waste determination, the reviewer should evaluate the expected costs and benefits of additional radionuclide removal. If a waste determination is submitted prior to the termination (or beginning) of radionuclide removal activities, the reviewer should evaluate the practicality of removal of radionuclides to a greater extent than proposed in the waste determination. The costs and benefits of various radionuclide removal options often are compared in a supporting analysis presented with a waste determination (e.g., Gilbreath, 2005).

As discussed in Section 2.4.3, the NDAA allows for a broader range of factors to be considered in the evaluation of the practicality of waste removal than allowed by the Manual for DOE Order 435.1 or the West Valley Policy Statement. However, the NRC staff believes that these factors should be quantified, to the extent possible, to facilitate comparison of options. For example, in reviewing the waste determination for salt waste disposal at the Savannah River Site, the NRC staff considered the potential costs of schedule impacts, facility slowdown, and tank space issues in evaluating the practicality of additional removal of highly radioactive radionuclides (NRC, 2005).

3.4.1 Areas of Review

The reviewer should evaluate DOE's description of the potential risks, costs, and benefits associated with various options for radionuclide removal. The reviewer should expect that costs could include, but not necessarily be limited to, financial costs, delays, increases in risks to workers and members of the public, and system impacts (e.g., generation of secondary waste streams requiring storage in tanks). Benefits may be quantified in terms of decreases in radiological risks to workers and members of the public (including inadvertent intruders). In general, the comparison of potential costs and benefits should be quantitative to the extent practical, but qualitative information that may be useful in the comparison of various options (e.g., potential environmental benefits) also should be considered. Furthermore, in some cases qualitative differences are recognized and purely quantitative comparisons may be inappropriate. For example, radiological risks for workers are not directly comparable, on a quantitative basis, to predicted doses to members of the public because worker risks are accepted risks, whereas members of the public are likely to be unaware of, and may derive no benefit from, the actions that could lead to a radiological dose.

In reviewing the technical basis for the estimated costs of each alternative strategy, the reviewer should evaluate the uncertainties associated with component costs of each alternative. For example, the costs of major pieces of equipment are likely to be more certain than the costs of technology development, and, consequently, the reviewer should carefully examine the basis for the estimated cost of technology development if the cost of technology development dominates the cost of a particular option. In addition, the reviewer should evaluate how different types of costs are included in the cost-benefit analysis. For example, accounting for the costs of a piece of equipment that will be used for only one waste management activity is expected to be simpler than appropriately attributing the costs of technology development that may be applied to many activities.

In general, the level of detail of the review should be based on the level of detail necessary to distinguish between various options and to compare the practicality of additional removal with the practicality of completed removal activities or other proposed waste management activities. In many cases, a simplified screening analysis may be sufficient to eliminate particular waste management alternatives. However, in other cases, more detailed cost-benefit analyses may be necessary to evaluate the practicality of a proposed approach. General guidance on cost-benefit analysis is discussed in several reports (NRC, 1997, Office of Management and Budget, 1992, 2003). NRC also has developed cost-benefit analysis guidance for environmental reviews (NRC, 2003a, Section 6.7) and for site decommissioning (NRC, 2003b, Vol. 2, Appendix N). Cost-benefit assessment for a hypothetical low-level waste disposal facility is described in the Draft Environmental Impact Statement prepared by NRC for 10 CFR Part 61 (NRC, 1981, Vol. 2, Section 3.8). Although these guidance documents are not specific to all of the types of issues that are to be considered in the DOE waste determinations, many of the underlying principles and methods may be applicable.

However, if general guidance is applied, the reviewer should be mindful of limitations of the applicability of the metrics and procedures used in the guidance documents. For example, guidance for ALARA analyses for NRC licensees undergoing decommissioning (NRC, 2003b, Vol. 2, Appendix N), recommends that the potential benefits of remediation activities be quantified in terms of collective dose using a conversion factor of $2,000 per averted person-rem. The basis for the $2,000 per averted person-rem conversion factor is discussed in NUREG-1530 (NRC, 1995a). Because the period of analysis for a decommissioning facility is 1,000 years, the collective dose conversion factor used in the decommissioning guidance (NRC, 2003b, Vol. 2, Appendix N) includes predicted doses to individuals exposed to radioactivity from the site up to 1,000 years after site closure, with a discount function applied to the monetary value associated with averted future doses. NRC decommissioning guidance may be directly applicable to license modification or termination at the West Valley site (see Section 2.3), but not necessarily to the waste determination process addressed in this review plan. Cost-benefit analyses performed to support waste determinations for the West Valley site, like waste determinations for Hanford, SRS, and INL, may use some of the methods outlined in the decommissioning guidance, but other parts of the guidance may be inapplicable. For example, factors for converting averted collective dose to financial benefit may not be appropriate for use in waste determinations. In addition, the NRC staff previously has recommended that the monetary value associated with averted future doses not be discounted in analyses relevant to LLW disposal facilities (NRC, 2000).

More fundamentally, there may be differences between metrics used in ALARA analyses applied to NRC licensees and metrics appropriate for application to remediation activities performed by the Federal Government. Thus, NRC expects that the review of cost-benefit analyses for waste determinations will involve comparisons to other DOE activities. For example, to evaluate removal operations that have been performed, the reviewer should evaluate the financial costs of the radionuclide removal efforts and the associated reductions in predicted doses (including uncertainties in predicted doses). To evaluate the practicality of additional removal, the reviewer should evaluate the predicted costs of additional removal efforts and the predicted dose reductions associated with additional radionuclide removal (including uncertainties in both predicted costs and predicted doses). In both cases, the reviewer should evaluate DOE's basis for concluding that the financial cost per averted dose supports the conclusion that highly radioactive radionuclides have been removed to the maximum extent practical. To assess the practicality of additional radionuclide removal, the reviewer should evaluate information provided by DOE that shows that the financial cost per averted dose for any additional removal would exceed the cost per averted dose of other similar DOE activities.

3.4.2 Review Procedures

The reviewer should evaluate the risks, costs, and benefits associated with alternative waste management strategies and radionuclide removal technologies to determine whether there is sufficient technical justification to conclude that waste removal is complete, or whether it is practical to achieve further radionuclide removal. In conjunction with the review described in Section 3.3, the reviewer should support a decision regarding the practicality of additional radionuclide removal by following these review procedures:

- Confirm that the cost-benefit analysis includes a site-specific description of the affected environment, alternative waste management strategies considered, and different removal technologies evaluated. Confirm that estimated benefits of the different radionuclide removal technologies and waste management strategies are clearly stated (e.g., by estimating the reduction in risk or dose to the public, workers, and/or the environment over time that is associated with various options).

- Determine whether information about radionuclide removal technologies used in the cost-benefit analysis is reasonably current. Specifically, confirm that the most appropriate technologies have been considered in the cost-benefit analysis (see Section 3.3) and verify that the extent of radionuclide removal that could be achieved is not underestimated.

- Verify that the potential benefits of additional removal are consistent with the results of the performance assessment (Section 4) and inadvertent intruder analysis (Section 5). Ensure that potential uncertainties in dose predictions are adequately represented in the cost-benefit analysis (i.e., if doses could be significantly greater than doses assumed in the cost-benefit analysis, the cost per averted dose of removing additional radionuclides could be significantly lower than calculated in the cost-benefit analysis).

- If a detailed cost-benefit analysis is presented, ensure that the methods and values used (e.g., discounting methods and discount rates) are appropriate. A reviewer may compare the methods and values used with NRC guidance such as NUREG–1757 (NRC, 2003b, Vol. 2, Appendix N), if appropriate. Appropriate values for use in waste determinations may be different from the values recommended in guidance applicable to other types of sites (e.g., the period of performance).

- Determine whether the applicability of costs and benefits have been accounted for appropriately. For example, if a technology must be developed to remove a component from a particular waste stream (e.g., the removal of zeolite from a tank, or the removal of technetium from salt waste) it may not be appropriate to attribute the entire cost of technology development only to the proposed waste management activity if other relevant benefits of the new technology (e.g., removal of zeolite from other tanks, or removal of technetium from other salt waste streams) are not included in the analysis.

- Determine whether the cost-benefit analysis includes relevant life-cycle costs, including variable costs (e.g., labor) and fixed costs (capital equipment). Verify that estimated costs and benefits are expressed in monetary terms where possible and expressed in constant dollars from the most recent year for which adjustment data are available.

- If a detailed cost-benefit analysis is presented and if life-cycle costs are to be distributed over time, verify that the cost-benefit analysis has used adequate discounting methods such as those described in Office of Management and Budget (OMB 2003, Circular A–4; 1992, Circular A–94).

- Verify that the timeframe(s) considered in the cost-benefit analysis are appropriate to the alternative waste management strategies and different removal technologies considered and include both short-term and long-term impacts.

- Determine the effect of any cited schedule impacts on the estimated cost or predicted doses to individuals (workers or members of the public).

- Evaluate whether additional protective measures could be taken to reduce worker exposure if radiological risks to workers are cited as a reason why additional radionuclide removal is impractical. If possible, determine whether taking additional protective measures to reduce worker exposure would contribute significantly to the cost of the proposed radionuclide removal activities.

- Determine whether any activities that DOE concludes are impractical are appropriately consistent with previous and proposed DOE waste management strategies. Specifically, if appropriate data exist, compare the predicted costs of additional radionuclide removal to the costs incurred to perform similar removal activities at the site (e.g., the costs of previous efforts to remove radionuclides from the same tank, or the costs to remove a similar type of waste from a tank at the same site). If the incremental cost of performing additional radionuclide removal operations is not significantly greater than the costs available for comparison, determine whether it is appropriate to conclude that additional removal efforts would not be practical.

3.5 Concentration Limits

As discussed in Section 2.4.4, the NDAA, DOE Order 435.1 (DOE, 2001), and the West Valley Policy Statement (NRC, 2002) have different requirements regarding the classification of incidental waste according to the waste classifications described in 10 CFR 61.55. Essentially, the NDAA requires waste classification according to NRC's classification system, DOE Order 435.1 requires classification according to NRC's classification system or an alternate system approved by DOE, and the West Valley Policy Statement does not address waste classification with respect to incidental waste.

3.5.1 Areas of Review

To evaluate compliance with the applicable criteria of the NDAA and DOE Order 435.1, reviewers should assess DOE's classification of incidental waste according to the provisions of 10 CFR 61.55. Because NRC's waste classification system is based on radionuclide concentrations, the reviewer should start by reviewing radionuclide concentrations as described in Section 3.1. The concentration averaging provision of 10 CFR 61.55(a)(8) is applicable to the determination of the class of waste that has been mixed with or encapsulated within stabilizing material (e.g., residual tank waste stabilized with grout). Section 3.5.1.1 provides guidance to reviewers evaluating the use of the concentration averaging provision of 10 CFR 61.55(a)(8). Section 3.5.1.2 addresses the consultation requirements of the NDAA that are related to waste classification. The use of stabilizing material to protect inadvertent intruders is discussed in Section 5, and the use of stabilizing material to enhance site stability is discussed in Section 7.

3.5.1.1 Concentration Averaging

The guidance for concentration averaging in this review plan does not replace the guidance contained in the branch technical position (BTP) on concentration averaging and encapsulation (NRC, 1995b) for the purposes of waste classification for the commercial disposal of low-level waste. The guidance is not intended to address all unique situations at DOE sites. However, this guidance is generally applicable to the following scenarios:

- Underground waste storage tanks including heels, cooling coils, and residuals adhering to walls and other surfaces,
- Infrastructure used to support underground waste storage tanks such as transfer lines, transfer pumps, and diversion boxes,
- Waste removed from tanks that is processed or treated for disposal in a near surface disposal facility, and
- Other scenarios relating to waste determinations proposed by the DOE and accepted by the NRC.

Although the concentration averaging BTP was not written to address residual contamination of underground or buried structures or systems, the fundamental principles contained within the BTP are applicable to these systems. This concentration averaging guidance clarifies the fundamental principles presented in the BTP and provides specific examples that may be pertinent to DOE waste determinations. The acceptable methods for concentration averaging for the purposes of waste classification for waste determinations are based on the following fundamental principles introduced in the BTP:

- Measures are not to be undertaken to average extreme quantities of uncontaminated materials with residual contamination solely for the purpose of waste classification.

- Mixtures of residual waste and materials can use a volume or mass-based average concentration if it can be demonstrated that the mixture is reasonably well-mixed.

- Credit can be taken for stabilizing materials added for the purpose of immobilizing the waste (not for stabilizing the contaminated structure) even if it cannot be demonstrated that the waste and stabilizing materials are reasonably well-mixed, when the radionuclide concentrations are likely to approach uniformity in the context of applicable intruder scenarios.

- Other provisions for the classification of residual waste may be acceptable if, after evaluation of the specific characteristics of the waste, disposal site and method of disposal, conformance of waste disposal with the performance objectives in Subpart C of 10 CFR Part 61 can be demonstrated with reasonable assurance.

- Regardless of the averaging that is performed for waste classification purposes, the performance assessment or other approach used to demonstrate compliance with the performance objectives of 10 CFR Part 61, Subpart C must consider the actual distribution of residual contamination in the system when estimating release rates to the environment and exposure rates to inadvertent intruders. Conservative assumptions regarding the distribution of contamination are appropriate.

The purpose of these principles is to prevent arbitrary or incorrect classification of materials that may result in near-surface disposal of materials that are not suitable for near-surface disposal. Appropriate concentration averaging may indicate that waste exceeds Class C concentration limits. Waste that exceeds Class C concentration limits may be suitable for near-surface disposal, but the evaluation of the suitability must involve independent analysis such as would be performed by the NRC under 10 CFR 61.58. The methods described in the two categories that follow can be used to determine the waste classification of waste residuals. As indicated by the first principle above, extreme measures should not be taken when performing concentration averaging to determine waste classification. Extreme measures include: 1) averaging assumptions that are inconsistent with the physical distribution of radionuclides over the averaging volume or mass, 2) deliberate blending of lower concentration waste streams with high activity waste streams to achieve waste classification objectives, or 3) averaging over stabilizing material volume or masses that are not needed to stabilize the waste per the 61.56 stability requirement or are not homogeneous from the context of the intruder scenarios. This guidance presents two categories of calculations of the concentrations of radionuclides in waste to be used to determine waste classification. The first pertains to cases in which the waste can be mixed and is fairly homogeneous. The second pertains to cases in which the waste cannot be removed or well mixed, and is stabilized in place to satisfy the requirements of 10 CFR 61.56. Other provisions may be used in performance assessment calculations to determine the suitability of near-surface disposal according to 10 CFR 61.58, but these other provisions do not pertain to the determination of whether a waste is Class A, Class B, Class C, or greater than Class C as defined in 10 CFR 61.55.

Category 1. Physical Homogeneity

In general, waste will have been processed to the maximum extent practical and will have been stabilized so that there is reasonable assurance that the performance objectives of 10 CFR Part 61, Subpart C can be achieved. The concentrations of radionuclides in the waste for waste classification can be based on the average concentration calculated from the total volume or mass of the waste and processing or stabilizing materials if the materials are reasonably well-mixed. For Category 1, the weight or volume of the container should not be included in the calculation of average concentrations. The primary consideration is whether the distribution of radionuclides within the final wasteform is reasonably homogeneous. Technical basis should be provided (e.g., sampling results, engineering experience, operational constraints) to demonstrate that the waste is reasonably well-mixed. The preferred method to demonstrate homogeneity would be to provide a statistical measure of the variability of concentration within the waste, although it is recognized that this may not always be practical. For homogeneous mixtures, the classification of waste residuals may be based on total volume or mass of the final wasteform. If additional averaging (e.g., as in the examples in Category 2) is not applied, waste with radionuclide concentrations after mixing that are greater than the values provided in Tables 1 and 2 of 10 CFR 61.55 would be considered to be greater than Class C waste.

Mixing within waste or of waste with stabilizing materials may be needed for a variety of reasons. Mixing of waste and stabilizing materials may be advantageous to reduce release rates in order to achieve performance objectives. As defined with respect to the principles of the BTP, mixing with excessive amounts of stabilizing materials solely to reduce the waste concentrations to alter waste classification should not be performed. In most cases, the ratio of the unstabilized to stabilized radionuclide concentrations would not be significantly greater than a factor of 10 for waste classification purposes. For unstabilized waste that cannot be selectively treated or removed, mixing (within waste, not between waste streams) to facilitate homogenization of radionuclide concentrations is appropriate. For example, mixing may be used to reduce the variability in concentrations within a layer of tank waste that cannot be removed for further treatment.

Example 1-1 - Liquid waste is removed from a tank and additional fluids are added in order to adjust the chemistry for processing. Cement and fly ash are mixed with the resultant liquid in an industrial mixer to form a grout that is placed in disposal containers. The concentration of radionuclides for determining waste classification is based on the total volume or mass of the final wasteform.

Example 1-2 - Reducing grout is added to stabilize a tank heel. The waste residuals in the tank are flocculated solids suspended in a liquid phase that can be mobilized with the tank transfer equipment. However, the solids cannot be removed with the existing equipment. The reducing grout has a relatively high viscosity, such that the flocculated solid residuals and remaining waste liquids can be mixed with the grout prior to setting with the transfer equipment. The concentration of radionuclides for waste classification is based on the total volume or mass of the waste and the reducing grout in which the waste is mixed. Additional reducing grout into which little or no waste is mixed should not be included in the total mass or volume used for concentration averaging.

Category 2. Stabilization to Satisfy 61.56

Stabilization is a factor in limiting exposure to an inadvertent intruder because it provides a recognizable and non-dispersible waste. For solidified liquids and solids, Section 3.2 of the BTP provides for the concentration of the radionuclides to be determined based on the volume or weight of the solidified mass, which is defined here to be the amount of material needed to stabilize the liquids or dispersible solids to satisfy 10 CFR 61.56. Liquid waste must be solidified or packaged in sufficient absorbent material to absorb twice the volume of the liquid (10 CFR 61.56). However, the stabilizing material is not to be interpreted as bulk material added to fill void space. Stabilization is determined with respect to the waste and not the entire disposal system or unit. While stabilization of the entire disposal unit (e.g., a tank) may be necessary to meet the performance objectives, it generally would not be needed to make the residual waste recognizable and non-dispersible.

Waste concentrations are calculated based on the volume or mass of material needed to be added to liquids or dispersible solids in order to solidify or encapsulate them. The concentration of the stabilized waste (waste plus stabilizing material) should generally be within a factor of 10 of the concentration on either a mass or volume basis in the unstabilized waste. The factor of 10 is derived from consideration that most stabilization techniques commonly envisioned use cementitious materials, and most cementitious wasteforms can readily achieve a ten mass percent waste loading. Additional stabilizing materials would in general not be needed for waste stabilization but may be needed for stabilization of the system or structures.

For thin layers of contamination on surfaces, especially vertical surfaces, the average concentration may be based on the volume or mass of the structure plus a layer of stabilizing material that would be needed to stabilize the waste, as discussed above. This is not to be interpreted to mean that averaging can be performed over all materials added to fill void space in the structure. This approach is justified because the concentrations would be expected to approach homogeneity with respect to the intruder scenarios, and the main justification for the classification system is to provide protection to the inadvertent intruder. The concentration values found in Tables 1 and 2 of 10 CFR 61.55 were derived assuming the total volume of waste exhumed by the intruder is at those concentrations, therefore a thin layer of more concentrated material averaged over the same exhumed volume would achieve a similar level of protection. Specific averaging volumes are not provided in this guidance because of the site-specific nature of the waste and site-specific considerations for intruder scenarios.

Example 2-1 - A tank contains a heel that is 2.5 cm thick, and is composed of liquids and dispersible solids. A 20-cm-thick layer of reducing grout is needed to stabilize the waste, and an additional 300 cm of high-strength grout is added to fill void space and to provide an intruder barrier. The concentration of radionuclides would be calculated by averaging over the 20-cm-thick layer of reducing grout. Use of a 20 cm layer of reducing grout in the concentration calculation is based on the amount of grout that would be needed to stabilize the waste if it could be removed from the tank and made into a stable wasteform. The concentration of the stabilized waste (waste plus stabilizing material) would generally be within a factor of 10 of the concentration in the unstabilized waste on either a mass or volume basis.

Example 2-2 - The walls of a waste storage tank have a thin layer (0.1 cm) of residual contamination that is not easily removed. The tank walls are 1 cm thick and the tank is contained within a 0.5-m-thick vault. The contamination is not easily dispersed into the *environment and is located underground. Closure of the storage tank will involve filling the tank and all void space with grout. The concentration of the waste for waste classification is calculated based on the thickness of the tank wall, the thickness of the contamination, and a 1-cm-thick layer of stabilizing grout. Use of a 1 cm layer of grout in the concentration calculation is based on the assumption that formation of a stable wasteform is accomplished by incorporating the 0.1 cm layer of residual waste into a cementitious wasteform at a mass loading of approximately 10%. The concentrations of the thin layer would be reduced by a factor of 20 for estimating waste classification if a volume basis were used.*

<u>Other Provisions</u>

10 CFR Part 61.58 allows the Commission to authorize other provisions for the classifications and characteristics of waste, if after evaluation of the specific characteristics of the waste, disposal site, and method of disposal, it finds reasonable assurance of compliance with the performance objectives in subpart C. Demonstration that the performance objectives can be satisfied would involve a site-specific analysis (e.g., performance assessment). 10 CFR Part 61.58 was intended to allow the NRC to establish alternate waste classification schemes when justified by site-specific conditions, and does not affect the generic waste classifications established in 10 CFR 61.55. Thus, if the results of concentration calculations performed in a manner consistent with the principles and examples described previously in this document indicate that radionuclide concentrations in the waste exceed Class C limits, then the waste is greater than Class C waste for waste classification purposes. If it can be demonstrated that the performance objectives of 10 CFR Part 61.58 can be satisfied, then the waste would be suitable for near surface disposal.

For the performance assessment calculations the waste should be represented as it is physically expected to be present, and not be averaged over the stabilizing and encapsulating materials unless the estimated doses to the public and inadvertent intruders were conservative as a result of averaging. Otherwise, every attempt should be made to represent the expected distribution of activity within the disposal system. If the 10 CFR 61 Subpart C performance objectives can be met with reasonable assurance, then the waste is considered to be acceptable for near surface disposal.

When performing the intruder calculations, it is not appropriate to calculate an average dose factoring in the likelihood of the occurrence of the scenario. The likelihood of the intruder scenario occurring is already represented in the higher limit (e.g., 500 mrem/yr) applied for inadvertent intruder regulatory analysis.

Example 3-1 - A waste heel remains in a HLW tank. Reducing grout is added to the heel, displacing some material to the center of the tank, while a fraction of the waste remains on the tank surfaces encapsulated by the reducing grout. A high strength grout is placed over the reducing grout as an intruder barrier and to limit water contact. The top of the waste residuals are 10 meters below the ground surface.

An intruder scenario is evaluated in which a well-driller places a well through the disposal system. In this case, the intruder is exposed to drill cuttings (waste). The average concentration of the waste used in the performance assessment calculations should be calculated by assuming mixing over the volume of well cuttings exhumed because the cuttings are expected to be well-mixed when spread on the land surface. This average concentration is *applicable only to the performance assessment and not to the determination of waste classification.*

Because the rate of erosion at the site is relatively high, a second intruder scenario is evaluated in which most of the cover is eroded over the analysis time period. Some cover is expected to remain. The intruder constructs a home in the area over the tank. Because the direct exposure pathway is the only major contributing pathway for this scenario, the actual waste distribution can be used in the performance assessment. Alternatively, the average concentration of waste over the stabilizing materials can be used in the performance assessment because there would be less shielding for this calculation and the doses would likely be conservative.

The doses to a public receptor who is offsite when institutional controls are in place and at the edge of a buffer zone near the closed tanks after institutional controls end is evaluated with an all-pathways performance assessment. The performance assessment represents expected degradation of the system over time. The modeling of the source term represents the waste as two zones, one zone of higher hydraulic conductivity and reducing conditions that persist for 500 years and one zone of lower hydraulic conductivity and reducing conditions that persist for the entire analysis period (10,000 years). The first zone represents waste between the tank surface and the added grout which may be exposed to increased moisture flow/oxidation because of shrinkage effects or degradation of the grout itself over time from various attack mechanisms. The second zone represents waste that was immobilized in the center of the reducing grout by the pour sequence of the tank closure operations. The concentrations of radionuclides in both zones should be represented in the performance assessment by the expected distribution of contamination within the zones, or distributions that can be demonstrated to be conservative with respect to release and exposure modeling. The potential pathways of water to the waste may depend on the discrete features of the system (e.g., cooling coils, shrinkage effects, fractures).

3.5.1.2 Consultation for Disposal Plans for Waste Exceeding Class C

Waste with concentration limits above the concentration limits for Class C LLW as defined in 10 CFR 61.55, although generally unacceptable for near-surface disposal, may be acceptable for near-surface disposal with special processing or design. The form and disposal methods for this waste must be different, and in general more stringent, than those specified for Class C waste (see 10 CFR 61.55(a)(2)(iv)). If DOE determines that the waste exceeds the Class C concentration limits, or if DOE is unable to determine whether the Class C limits are exceeded, the NDAA requires that disposal must be pursuant to plans developed by DOE in its consultation with the Commission (see Section 2.1).

The reviewer should take a risk-informed, performance-based approach when evaluating any disposal plans proposed by DOE during consultations. A risk-informed, performance-based approach provides DOE with the flexibility to define disposal methods for wastes that do not meet the Class C concentration requirements. In conducting its review, the staff should consider the following:

- How DOE's disposal plans, with respect to form and disposal methods, are different and, in general, more stringent than plans that would be proposed for disposal of Class C waste; and

- Demonstration of compliance with the performance objectives of 10 CFR Part 61, Subpart C (see Section 2 of this review plan). The review methods and acceptance criteria in Sections 4-7 of this review plan can be applied to evaluate performance assessments and facility designs intended to achieve compliance.

3.5.2 Review Procedures

The reviewer should evaluate the waste classifications provided in the waste determination using the information in 10 CFR 61.55. Specifically, the reviewer should confirm the following:

- The appropriate tables in 10 CFR 61.55 have been used to classify the waste.

- Uncertainties in concentrations that are used to determine waste classification have been considered appropriately (see Section 3.5).

- Classification has been made based on the final wasteform(s).

- The sum of fractions has been used correctly (10 CFR 61.55), if applicable.

- The waste concentration averaging guidance (see Section 3.5.1.1) has been applied appropriately. Specifically, if concentration averaging is applied, the reviewer should confirm the following:

  – Credit is taken only for material needed to stabilize waste rather than to stabilize a disposal facility (e.g., in most cases, the ratio of the unstabilized to stabilized radionuclide concentrations would not be significantly greater than a factor of 10 for waste classification purposes).

  – Radionuclide concentrations in waste to which concentration averaging is applied are likely to approach uniformity in the context of applicable intruder scenarios.

  – Different waste streams have been classified separately, if appropriate.

- In addition, if the waste exceeds Class C concentration limits, the reviewer should ensure that the consultation process described in Section 3.5.1.2 is applied appropriately.

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4 PERFORMANCE ASSESSMENT

This section provides guidance for the review of the performance assessment used by the U.S. Department of Energy (DOE) to evaluate dose for the nominal case (i.e., cases other than intruder scenarios) to demonstrate compliance with the performance objectives of 10 CFR 61.41. The term performance assessment can be used to refer to (1) the process of estimating future radiation doses to receptors or (2) a model or collection of models (e.g., process or submodels) used to estimate future radiation doses to receptors. In this review plan, the term performance assessment is used to refer to the process or the model(s) interchangeably. A performance assessment model may be a manually-integrated or fully-automated collection of individual models representing specific technical areas and processes. The individual models are commonly referred to as component models, process models, submodels, or abstractions. The review will encompass evaluation of scenario selection, the performance of the engineered system, the release and migration of radionuclides through the engineered barrier system and the geosphere, and radiation dose to the receptor groups. The review should be performed in a risk-informed manner, so that the reviewer is focused on those areas that have the largest effect on the estimated doses. Additional guidance on developing performance assessment and dose assessment models is found in NUREG–1573 (NRC, 2000) and NUREG–1757 (NRC, 2003a). Protection of inadvertent intruders (10 CFR 61.42) is discussed in Section 5, protection of individuals during operations (10 CFR 61.43) is discussed in Section 6, and site stability (10 CFR 61.44) is discussed in Section 7 of this review plan.

Typically a performance assessment is developed to demonstrate whether the performance objectives have been met. A performance assessment is a quantitative evaluation of potential releases into the environment and the resultant radiological doses. Depending on the computational tools used by the analyst, the performance assessment may be a single integrated model, or it may represent an analysis approach for integrating and evaluating a collection of other models. Performance assessments may involve the integration of process models to identify and propagate impacts and uncertainties between models. Process models are used to evaluate physical and chemical phenomena such as the release of radionuclides from wasteforms, degradation of engineered components, and transport of radionuclides through environmental media. Abstraction is a term used to describe the simplification of information in a performance assessment. A process model may be a detailed three-dimensional saturated zone flow and transport model whereas an abstraction may be a simple one-dimensional flow tube. Results of a detailed process model (e.g., for infiltration) or a complex data set may be abstracted into a lookup table or probability distribution to be sampled during execution of the performance assessment model. It is not necessary to preserve all of the information for explicit representation in the performance assessment model, rather abstractions can and are expected to be used to facilitate faster execution of the model and facilitate analysis of the results. The degree of abstraction in a performance assessment model (e.g., a highly-abstracted, simplified model or a direct integration of complex process models) typically represents a balance between practical aspects (e.g., maintaining computational efficiency, allowing for efficient modification of the model, and ensuring the model can be relatively easily understood and evaluated) and preserving details that may significantly impact the results. In general, the complexity of the performance assessment should be commensurate with the amount of support to justify the results of the assessment. This review plan provides a consistent set of areas of review and review procedures to ensure uniformity of reviews performed for different sites by different teams of reviewers. However, the review plan also affords flexibility to the reviewer to perform a more detailed review of particular elements of the performance assessment if justified by the risk significance of the elements (See Sections 4.2 and 4.6).

The performance assessment documentation will commonly provide the justification for the data used, a description of the models used, verification of and support for the models, and an evaluation of the impact of data and model uncertainty. To evaluate uncertainty, a variety of techniques typically are used, including deterministic analysis with sensitivity analysis, and probabilistic analysis with uncertainty and sensitivity analyses. The results of the sensitivity analysis may be used to conduct a risk-informed evaluation through the in-depth review of those parameters and processes most important to system performance with respect to meeting the performance objectives.

In general, different approaches to performance assessment calculations (e.g., deterministic, probabilistic) have their advantages and disadvantages. A deterministic approach can be very valuable when the analysis is clearly conservative, because it makes the demonstration of meeting the performance objectives more straightforward and it can be significantly easier to interpret results and explain them to stakeholders. While deterministic analysis can be a suitable methodology for performance assessment, it can also present a challenge when used to represent a system that responds in a highly nonlinear fashion with changes in the independent variables. In addition, when there are numerous inputs (e.g., data or models) that are uncertain, the evaluation of the impacts of the uncertainties on the decision can be a challenge with a deterministic analysis. Typical one-off type of sensitivity analysis (e.g., where a single parameter is increased or decreased) will only identify local sensitivity within the parameter space, such that it may not clearly identify the risk implications of the uncertainty in the parameter. A probabilistic approach can have distinct advantages when there are a number of uncertainties that may significantly influence the results of a performance assessment or when the interdependence of parameters or assumptions is not clear (e.g., for highly nonlinear problems). However, there are limitations to probabilistic analysis, such as limited data to define parameter distributions and inappropriate impacts on the performance metric (e.g., peak mean dose) resulting from selection of overly broad parameter distributions, particularly for parameters that affect the timing of doses. Even with a probabilistic approach, conceptual model uncertainty may not be explicitly represented and therefore could not be assessed with uncertainty analysis.

The term “conservatism,” as used with respect to performance assessment, is a relative term. Conservatism is typically defined mainly with respect to what is known, or sometimes with standard practices that have been demonstrated to yield acceptable performance (e.g., a safety factor used in the design of a bridge). The use of the term “conservatism” with respect to performance assessment, is typically more conjectural in nature. For example, a parameter value may not be measured and therefore the analyst will attempt to select a conservative value based on professional judgement. If a large amount of data is available to support a performance assessment model, less conservatism would be needed in the analysis. In this regard, model support (i.e., information that supports the results of a model) of process model results plays a key role in developing confidence in the output of performance assessment calculations. Because of the long time periods that performance of the system is being estimated for, performance assessment models cannot be validated in the traditional sense. However, multiple methods for developing confidence in the model projections can be used, including: laboratory experiments, alternative modeling approaches, field measurements, natural analogs, and expert elicitation, among others. The amount of model support provided should be commensurate with the risk reduction being provided by the natural and engineered system. Multiple lines of evidence are strongly encouraged when the risk reduction of the systems being evaluated is large.

This section of the review plan discusses scenario selection and receptor groups (Section 4.1), general technical review procedures (Section 4.2), specific technical review procedures for such areas as infiltration, engineered barriers, and source term (Section 4.3), computational models and computer codes (Section 4.4), uncertainty/sensitivity analysis (Section 4.5), evaluating model results (Section 4.6), and evaluating whether releases are as low as reasonably achievable (Section 4.7).

During the technical review performed following the guidance in this section, the reviewer should identify those factors that are important to assessing compliance with 10 CFR 61.41. By application of this review plan, the reviewer should determine if adequate support has been provided for important assumptions, data, and models. Important factors may need to be confirmed or verified during the monitoring process for a variety of reasons, such as incomplete information or the fact that an engineered system may not be installed until system closure. As outlined in Section 10 of this review plan, those factors will be emphasized during monitoring by the NRC. The reviewer should consider the sensitivity and uncertainty analysis and barrier analysis information presented by DOE and discussed in Sections 4.5 and 4.6, respectively. Information supporting the performance estimates of the natural and engineered systems with the largest risk reduction should be noted and emphasized in monitoring, as appropriate.

4.1 Scenario Selection and Receptor Groups

Scenario analysis is typically the initial step in the model development (or selection) process. Evaluation and selection of applicable features and processes at the disposal site and the surrounding region supports the conceptualization of the total system (e.g., disposal site and surrounding area) and provides confidence in the completeness of the performance assessment model. A scenario description should serve as a broad conceptual roadmap for the performance assessment model, emphasizing those key features and processes that influence the release, transport, and dose from the release of radioactive materials from the disposal site. The scenario description should provide sufficient information to understand the general spatial domain and conceptualization of the performance assessment model including release location(s), applicable radionuclide transport pathways, and the location and general characteristics of the receptor(s).

4.1.1 Areas of Review

This section focuses on ensuring that appropriate scenarios for radionuclide release, transport, and exposure of a receptor group have been considered for evaluation in the performance assessment. The process for developing scenarios to evaluate in the performance assessment typically include the following steps: (1) scenario identification, (2) identification of relevant features and processes, and (3) development of receptor characteristics. The period of performance evaluated will influence the development of scenarios for the performance assessment.

4.1.1.1 Period of Performance and Institutional Controls

Generally, a period of 10,000 years is sufficient to capture the peak dose from the more mobile, long-lived radionuclides and to demonstrate the influence of the natural and engineered systems in achieving the performance objectives (NRC, 2000). However, assessments beyond 10,000 years may be necessary to ensure that the disposal of certain types of waste does not result in markedly high doses to future generations, or to evaluate waste disposal at arid sites with extremely long groundwater travel times. Periods of performance shorter than 10,000 years are generally not appropriate for disposal facilities for incidental waste, because of the larger fraction of long-lived radionuclides compared to a typical commercial low-level waste (LLW) disposal facility. Presenting and understanding long-term risk (e.g., greater than 10,000 years) can be an important part of performance assessment analyses, even if those risks are not used to demonstrate compliance with the performance objectives of 10 CFR Part 61, Subpart C.

The regulations in 10 CFR 61.59(b) specify that institutional controls may not be relied upon for more than 100 years. At the time of development of 10 CFR Part 61, it was envisioned that low-level waste in a disposal facility would decay, in a maximum of 500 years, to activity levels that would not pose a significant risk to an inadvertent intruder and that there would not be significant quantities of long-lived isotopes which would pose unacceptable long-term risks to the public from releases from the facility. In developing 10 CFR Part 61, NRC considered longer periods of institutional control in the Draft Environmental Impact Statement (NRC, 1981). Assumptions about the persistence of institutional controls in the international community were considered and a series of public meetings were conducted to get input from stakeholders. The consensus among the stakeholders was that it is not appropriate to assume institutional controls will last for more than a few hundred years. Material that does require institutional control for much longer than 100 years to demonstrate compliance with the performance objectives would generally be determined to not be suitable for near surface disposal as low-level waste. The regulatory philosophy is that the engineered and natural system should afford protection to the public, without total reliance on institutional control of the site, because of the relatively large uncertainty associated with predicting societal systems.

4.1.1.2 Scenario Identification

It is generally acceptable to conduct performance modeling based on scenarios such as those described in NUREG–1757 (NRC, 2003a, Vol. 2, Appendix I). Scenarios used in the performance assessment should generally include consideration of site-specific data and information about the characteristics of the site and surrounding region (including local practices), potential disruptive processes, and temporal behavior of the engineered and natural barriers. As necessary, the scenarios that are evaluated in the performance assessment should be constrained in a manner consistent with the relevant guidance provided in this review plan (e.g., scenarios should be based on past, current, and projected future activities at the site).

Release and transport scenarios are likely to involve mobilization of waste by infiltrating water, contamination of local groundwater and/or surface water, and subsequent use of contaminated groundwater or surface water for domestic, agricultural, and recreational purposes by receptors. Gaseous releases to air may also need to be addressed at the release location and perhaps at the receptor location (e.g., emanation from groundwater) at some sites. Receptor characteristics and exposure scenarios may vary from site to site, however, drinking water and agricultural food production (crops, livestock) are common practices that contribute to the intake of radionuclides by many types of receptors. External exposure to contaminated soils and inhalation of resuspended contaminants also are common exposure pathways. Recreational use of surface water (e.g., fishing and swimming including exposure to contaminated sediments) may be relevant features at some sites.

The reviewer should ensure that appropriate exposure pathways are included in the performance analyses or that technical justification is provided to explain why certain pathways may not be applicable for a particular site. For example, common exposure pathways include ingestion, inhalation, and external exposures. Transport pathways may be excluded from performance analysis if it can be demonstrated that either there is limited potential for radionuclides to be released into a particular pathway, or the pathway is not viable (e.g., water is not potable). Specific review guidance for factors that must be considered for the inadvertent intrusion exposure scenario is discussed in greater detail in Section 5. Additional guidance for reviewing protection of individuals during operations is provided in Section 6.

4.1.1.3 Identification of Relevant Features and Processes

Prior to conducting detailed technical reviews of the performance assessment model, it is important to ensure the scenario(s) are sufficiently described and documented to confirm that key features and processes have been included in the overall system model. An acceptable dose assessment analysis need not incorporate all the physical, chemical, and biological processes at the site. The reviewer should ensure that the scope of the analysis and the level of sophistication of the conceptual models are suitable for demonstrating compliance with performance objectives in 10 CFR Part 61, Subpart C. Examples of features and processes that are commonly considered include air, soil, groundwater, surface water, plant uptake, and exhumation by burrowing animals. Transport and exposure pathways may be excluded from the performance assessment if it can be demonstrated that either there is no potential for radionuclides to be released into a particular pathway, or the pathway is not a viable transport or exposure pathway for the particular scenario (e.g., groundwater is not potable). The following list of general features and processes provides major elements that are expected to be considered when scenarios are developed for evaluation in the performance assessment. The scenarios developed for the performance assessment will be a function of the projected human activities at the site, features and processes of the engineered system, and features and processes of the natural system. Specific features and processes that should be considered when developing submodels of the performance assessment are reflected in the review procedures of the pertinent sections. Identification of relevant features and processes would typically consider the following:

- Human activities at the site with emphasis on local practices that could bring humans in contact with waste (e.g., water use, hunting, fishing, recreational activities such a swimming and boating, habitation in dwellings, other unique activities that involve water use or ground disturbance);

- The frequency and magnitude of disruptive processes (e.g., seismic events, floods, hurricanes) and their impact on the release of waste to the environment;

- The location of surface water bodies such as streams and rivers in relation to the waste disposal facility;

- The features of the site meteorology affecting transport of airborne contaminants, including stability class, wind speed, wind direction, temperature, and rainfall;

- Features of the disposal site that may influence the degradation of engineered systems and the release of radionuclides from those systems (e.g., the process of fluctuation in the shallow water table at the Savannah River Site [SRS] may influence oxidation and radionuclide release from the wasteform);

- The features and properties of the waste inventory, wasteform, and the facility design that define the release rate of radionuclides from the disposal facility (e.g., the low hydraulic conductivity of an intact cementitious wasteform may limit release of radionuclides to diffusional processes);

- Features of the disposal facility that may influence the release of radionuclides from the system (e.g., discrete pathways resulting from features of the system [such as sumps, piping or shrinkage of the wasteform within the disposal container]);

- Processes that influence the partitioning and mobility of the waste inventory (e.g., the presence of chelating agents in the waste);

- Processes that influence the ability of the wasteform to retain radionuclides (e.g., seismically induced fracturing of cementitious wasteforms);

- Features of local flora that may impact the release of waste (e.g., deep rooting species may reduce the effectiveness of an infiltration cap over time) or the uptake of contaminants by humans and animals;

- Features of local fauna that may impact the release of waste (e.g., burrowing animals may exhume waste from disposal areas) or the uptake of contaminants by humans and animals (e.g., deer may access contaminated vegetation or water sources that are not viable for human receptors);

- Physical and chemical properties of surface soils such as hydraulic conductivity, porosity, moisture characteristic curve parameters, erodibility, and distribution coefficients that may influence the process of water infiltration and the retention of radionuclides (e.g., sorption processes, erosion rates) at the disposal site;

- Physical and chemical properties of the saturated and unsaturated zones that influence water infiltration and sorption processes (e.g., soil type, mineralogy); and

- Features of the unsaturated zone (e.g., abandoned wells or fractures) that result in discrete transport pathways or, conversely, that will justify assuming porous flow.

The scenarios evaluated in the performance assessment should represent an integration of the relevant major features and processes at the site. The goal is to develop a set of reasonably anticipated natural conditions, processes, and events and their impact on the engineered disposal system to be represented in the site conceptual model. Processes impacting the long-term stability of the disposal site should also be considered in the development of scenarios for the performance assessment. For example, 10 CFR 61.13 provides specific processes that should be considered, including: erosion, mass wasting, slope failure, settlement of wastes and backfill, infiltration through covers over disposal areas and adjacent soils, and surface drainage of the disposal site. Guidance for reviewing analyses of site stability is provided in Section 7 of this review plan. Disruptive processes such as erosion, seismic disruption, or other natural hazards such as hurricanes, tornados, fires, or floods may impact the integrity of the disposal site and constitute potential release mechanisms. The reviewer should ensure that such processes are appropriately considered and that performance assessment scenarios are developed for those hazards that cannot be ruled out.

Specific review guidance for factors that must be considered for the inadvertent intrusion exposure scenario is discussed in greater detail in Section 5. Additional guidance for reviewing protection of individuals during operations is provided in Section 6.

4.1.1.4 Receptor Characteristics

Receptor characteristics may differ for air, groundwater, and surface water pathway scenarios and the receptor group lifestyle habits (e.g., regional differences) may differ accordingly. Receptor characteristics may also differ for onsite worker and public exposure scenarios, and for inadvertent intruder scenarios. The assumptions regarding receptor location and lifestyle habits must be appropriately integrated into the performance model.

In general, after the period of active institutional control period ends, to demonstrate compliance with 10 CFR 61.41 the public receptor should be assumed to engage in residential, agricultural, or other activities at the boundary of the disposal site. These activities should be consistent with regional practices. The disposal site includes a buffer zone around the disposal area, where the disposal area circumscribes the disposal units (NRC, 1982). An appropriate buffer zone is expected to extend approximately 100 m (330 ft) from the disposal area. In the case of a tank farm, the tanks are expected to be regarded as disposal units. Thus an appropriate buffer zone is expected to extend 100 m (330 ft) from the line circumscribing the tanks in a single tank farm or a similar distance that is supported by a technical justification. In some instances, such as with a complex hydrogeologic system or where there are multiple sources, the point of maximum exposure may be at a larger distance than the 100 m (330 ft) distance from the disposal unit. A receptor engaging in activities on the disposal site, rather than outside the buffer zone, is regarded as the inadvertent intruder for demonstrating compliance with 10 CFR 61.42. A receptor engaging in activities outside the buffer zone (e.g., outside the disposal site but on the current DOE site) is regarded as a member of the public.

4.1.2 Review Procedures

Details of the analysis related to the exposure pathways in the biosphere and dosimetry are largely determined by the scenario and the assumed behavior of the receptor. Accordingly, models related to the exposure pathways in the biosphere and dosimetry should not change from one site to another unless there is a significant change in the scenario and associated receptor behavior or location. In general, there are two primary areas of the dose analysis where the conceptual model is expected to change from one site to another; these are related to the source term (including the effects of engineered barriers on release) and environmental transport. The reviewer should ensure that site-appropriate source terms and transport pathway models are summarized in the conceptual model description. Source term analysis is discussed in Section 4.3.3, and the principal environmental transport pathways (groundwater [including transport through the unsaturated zone], surface water, and air) are discussed in Section 4.3.4. The reviewer should perform the following procedures:

- Ensure that the scenarios used in the performance assessment to demonstrate protection of the general population from releases of radioactivity include radionuclide transport pathways via groundwater, surface water, and air, or that a sufficient technical basis is provided for their exclusion. Transport pathways may be excluded from performance analysis if it can be demonstrated that either there is limited potential for radionuclides to be released into a particular pathway, or the pathway is not viable (e.g., water is not potable).

- Ensure that disruptive processes such as erosion or seismic disturbance, and natural events such as hurricanes, tornados, fires, or floods, have been appropriately considered in the scenario selection process. For example, erosion at a waste disposal facility may result in the need for development of performance assessment scenarios of waste transport via surface water pathways.

- Ensure that adequate technical basis has been provided for screening disruptive processes from representation in the performance assessment model and that impacts of disruptive processes which were not screened were implemented in the performance assessment models.

- Evaluate whether assumptions regarding receptor location and information defining lifestyle habits are appropriately chosen for each exposure scenario and each exposure pathway.

- Evaluate whether reasonable assumptions have been made for lifestyle habits considering local, regional and national (generic) sources of information.

- Determine if lifestyle habits based on regional practices may be less conservative than common generic lifestyle habits. Adequate technical basis should be provided for locally-defined lifestyle habits that are less conservative than commonly accepted lifestyle habits in generic dose assessments.

- Evaluate whether information for each scenario is presented in a clear and transparent manner (e.g., each pathway is listed, receptor characteristics and lifestyle behavior are described, maps showing potential receptor locations with respect to the disposal site are provided).

- Ensure that the public receptor location for evaluating compliance with 10 CFR 61.41 is at the point of maximum exposure outside the buffer zone (see Section 4.1.1.4).

- Ensure that the buffer zone has been appropriately defined, generally not to exceed 100 m (330 ft) from the disposal area.

- Ensure that the DOE has considered applicable features and processes that could significantly influence disposal site performance in developing its scenarios (see Section 4.1.1.3).

- Ensure that DOE has not taken credit for active institutional controls for more than 100 years.

- Ensure that the analysis estimated performance for a period of 10,000 years to demonstrate compliance with 10 CFR Part 61, Subpart C. A period of 10,000 years is generally sufficiently long to (1) evaluate performance of both engineered barriers and the site and (2) capture the peak doses from the most mobile long-lived radionuclides.

- Determine, if appropriate, that DOE has evaluated doses beyond 10,000 years (e.g., for strongly-sorbing radionuclides) and whether those doses are expected to be markedly higher than those evaluated for compliance with 10 CFR 61.41 (i.e., 10,000 years). If so, the reviewer should note in the Technical Evaluation Report the maximum doses expected to occur after 10,000 years.

- Determine if DOE has considered characteristics of the waste inventory such as activity, half-life, and mobility of radionuclides in determining whether the appropriate performance period should be longer than 10,000 years.

- Ensure that processes and conditions that control engineered barrier degradation, water infiltration, leaching of waste, and release and transport of radionuclides to the general environment have been considered in development of scenarios for the performance assessment.

- Ensure scenario descriptions and any associated figures or maps depicting scenarios are supported by and consistent with the system descriptions and information regarding regional features and practices.

- Verify that scenario descriptions are consistent with the models implemented in the performance assessment.

- Determine that appropriate exposure pathways are included in the performance analyses or that technical justification is provided to explain why certain pathways may not be applicable to a particular site. For example, common exposure pathways include ingestion via water, plants, animals, and soil, inhalation of gaseous or resuspended contaminants, and external exposures to contaminated soil or water. Recreational use of surface water (including exposure to contaminated sediments) may be relevant activities at some sites (e.g., fishing, swimming).

- Ensure the list of general features and processes provided in Section 4.1.1.3 have been considered by DOE in development of scenarios for implementation in the performance assessment.

- Verify that DOE has provided an adequate rationale for excluding features or processes that could significantly increase the magnitude of estimated doses or the time of estimated doses (e.g., fast pathways in the unsaturated zone that could result in rapid transport of short-lived contaminants such as Cs-137 and Sr-90 to potential receptors).

4.2 General Technical Review Procedures

The review should be focused on understanding the importance to performance of various assumptions, models, and data in the performance assessment. As discussed in Section 4, the performance assessment model can be a collection of other models (e.g., submodels or process models) of varying levels of complexity, or it can be an integrated model. Regardless of the form of the numerical representation, the performance assessment model will represent numerous physical processes (e.g., infiltration, degradation of engineered barriers, release and transport of radionuclides, exposure of receptors to radionuclides). There are general technical review procedures that are applicable for all parts of the DOE performance assessment model. This section identifies those review procedures that can be broadly applied. Specific review procedures are identified in Section 4.3. In general, the general technical review procedures can be divided into five separate categories:

- System Description: These review procedures are used to ensure that DOE has provided an adequate description of the performance assessment models and the overall disposal system, and that the different performance assessment models have been appropriately integrated (e.g., infiltration with source term release). The description should be adequate for the reviewer to understand the modeling and analyses, and if necessary, to perform independent analysis of the disposal system. (See Section 4.2.1.)

- Data Sufficiency: These review procedures are used to ensure that DOE has provided sufficient data to support the performance assessment models. The types of data to be considered may include site-specific data (e.g., laboratory measurements and field-scale measurements or experiments), data from analogous sites, data from generic sources, output from detailed process-level models, and expert judgement. (See Section 4.2.2.)

- Data Uncertainty: These review procedures are used to ensure that DOE has captured the variability in data and provided an assessment of uncertainty due to the incomplete knowledge of the natural system, engineered system, or inventory. Parameter uncertainty can be propagated through the performance assessment by distributions (probabilistic analysis) of variables such as hydraulic conductivity, porosity, or the retardation coefficient. In a deterministic analysis, the data uncertainty can be examined by the use of sensitivity analyses and bounded by the selection of conservative values. (See Section 4.2.3.)

- Model Uncertainty: These review procedures are used to ensure that DOE has evaluated the impact of model uncertainty and discussed the inherent uncertainties in applying predictive models: (1) over long periods of time for which direct validation is precluded; and (2) to complex systems for which measurement and characterization may be limited. These uncertainties can be evaluated in the performance assessment by considering reasonable ranges in conditions and processes to test the robustness of the facility, by using distributions of parameters to represent the likely ranges in conditions or processes, or by bounding the effects of model uncertainty by using conservative assumptions. Ideally, model uncertainty is minimized by developing as much model support as practical. (See Section 4.2.4.)

- Model Support: These review procedures are used to ensure that the output from the DOE performance assessment model results can be supported by comparison to independent data. In general, using these review procedures, the reviewer should expect to evaluate multiple lines of evidence supporting the selected model (e.g., field tests or laboratory tests that provide a technical basis for selecting a certain release mechanism). In addition, the reviewer may conduct independent analyses for comparison of process model results, or the model results may be compared to analogous systems. (See Section 4.2.5.)

To review the overall performance assessment, the reviewer should recognize that models used by DOE may range from highly complex process-level models to simplified models, such as response surfaces or lookup tables. The reviewer should evaluate the adequacy of the model and the supporting technical basis, regardless of the level of complexity. The reviewer should determine whether uncertainties in the models and parameters are appropriately accounted for in the DOE performance assessment. Specifically, the reviewer should follow the procedures given in Sections 4.2.1 through 4.2.5.

4.2.1 System Description Review Procedures

- Examine the descriptions of design features (including engineered barriers, wasteforms, and other engineered components) and the relevant natural system features (including the geological, hydrological, and geochemical aspects of the natural barriers at the site). Verify that the descriptions are sufficient to support the development of a conceptual model of the site, including major pathways for water and radionuclide movement.

- Assess that the design and natural system features have been adequately incorporated into the performance assessment. Where simplifications are used, confirm that the technical bases used to support the simplifications (e.g., modeling assumptions and approximations) are adequate (e.g., verify that the potential effects of the simplifications on dose predictions have been bounded) and have been documented in a transparent and traceable manner.

- Determine that the conditions and assumptions used in the performance assessment modeling are consistent with the documentation.

- Verify that the assumptions, data, and models used by DOE are consistent among the different parts of the performance assessment. For example, the release models used in the source-term model should be consistent with the chemical environment assumed for the engineered barrier system.

- Confirm that common boundary and initial conditions are consistent among submodels of the performance assessment (e.g., the recharge rate in saturated zone modeling should be consistent with infiltration applied to the unsaturated zone if there is not significant lateral flow in the unsaturated zone).

- Examine how features and processes related to the performance of the engineered and natural barrier systems have been included in the performance assessment model, and verify that performance through time has been adequately represented. For example, if the hydraulic conductivity of a barrier is expected to increase over time, verify that the hydraulic conductivity value(s) used in the performance is consistent with or bounds the expected degradation.

- Evaluate whether conceptual models sufficiently account for the most important physical, chemical, and biological processes at the site so that a more realistic representation of the site would not lead to higher dose estimates.

4.2.2 Data Sufficiency Review Procedures

- Confirm that the data used to support conceptual models, process-level models, and simplifications considered in the performance assessment are sufficient. Examine the parameters used for these models, and verify that the parameters are based on an adequate technical basis, such as data derived from laboratory experiments, site-specific field measurements, operational experience, research at comparable sites, and process-level modeling.

- Examine and confirm that DOE has provided sufficient data on the characteristics of the waste, engineered barriers, and natural system to establish initial and boundary conditions for models.

- Verify whether sufficient data have been collected to adequately model degradation of engineered barrier processes and near-field transport of radionuclides, as well as to establish important characteristics of the natural system (e.g., geochemistry, hydrology).

- Verify that parameter values are derived from site-specific data when available, or that an analysis is included to show that data from generic sources leads to a conservative assessment of performance.

- Verify that data from generic sources are appropriate for the site-specific conditions or materials in the performance assessment. For example, if distribution coefficients for cement are taken from Bradbury and Sarott, verify that the cement formulations used in the reference are consistent with the grout being used at the site (Bradbury and Sarott, 1995).

- Verify that experimental conditions for laboratory or field measurements (e.g., temperature, chemistry of a solution used in a leach test) are reasonably representative of expected system conditions, or that an adequate assessment of the impact of the differences in conditions has been provided.

- Confirm that parameter values used in process-level models are appropriate for the time- and space-scales of the performance assessment calculations.

- Examine the initial and boundary conditions of the models and verify that they are consistent with available data.

- Confirm that sensitivity or uncertainty analyses have been used to assess data sufficiency. If the analyses identified significant impacts associated with the uncertainty in particular data, evaluate additional data that was acquired or the plans to acquire information needed to limit the uncertainty in results to an acceptable range. As appropriate, document the associated assumption in the TER.

- If expert judgement is used as a basis for selecting parameter values where default model parameters or site-specific data are not sufficient, evaluate the methods used by DOE to develop the information, and confirm the information was developed from unbiased sources in a transparent and objective way (for example, see guidance in NUREG–1563 [NRC, 1996]).

- As appropriate, verify that DOE uses acceptable approaches to peer review and data qualification (see guidance such as NUREG–1297 and NUREG–1298 [NRC, 1988a,b]), or provides adequate justification for using alternative approaches.

4.2.3 Data Uncertainty Review Procedures

- If deterministic models are used in the performance assessment, evaluate the technical bases for parameter values, assumed ranges used in sensitivity analyses to characterize data uncertainty, and bounding values used in conceptual and process models.

- If a deterministic approach is used, verify that key parameter values are reasonably conservative, technical basis is provided for conservative assumptions, and the conservatism of values is defined on a total system level and not at the local level. For example, increasing the hydraulic conductivity of saturated zone aquifers to address uncertainty may be conservative with respect to contaminant travel time but may be non-conservative with respect to dose as a result of increased dilution of contaminant fluxes entering the saturated zone from the unsaturated zone.

- If probabilistic models are used in the performance assessment, evaluate the technical bases for parameter ranges, probability distributions, or bounding values. The reviewer should verify that the technical bases are adequate to support the treatment of uncertainty and variability of these parameters.

- Verify that uncertainty in initial and boundary conditions has been appropriately considered and is reflected in the performance assessment models.

- Confirm that uncertainty in data from both temporal and spatial variations has been incorporated into the parameter ranges (e.g., degradation of barrier performance with time, spatial variation of soil properties).

- Determine whether expert judgement was used as a basis for data uncertainty and confirm the information was developed from unbiased sources in a transparent and objective way (e.g., see guidance in NUREG–1563 [NRC, 1996]).

- If a probabilistic model is used, verify that DOE appropriately established possible statistical correlations between parameters. Verify that an adequate technical basis or bounding argument is provided for neglected correlations.

4.2.4 Model Uncertainty Review Procedure

- Examine the models used in the performance assessment in the context of available data such as design data and verification tests for engineered barriers and wasteforms, laboratory experiments, field measurements, monitoring data, and process-level modeling. Confirm that models in the performance assessment were developed considering the uncertainty and variability in supporting information.

- Verify that conceptual model uncertainties are adequately described and documented. Verify that the impact of model uncertainty on overall system performance was properly assessed.

- Examine the mathematical models included in the performance assessment. Evaluate the assumptions on which the selected models are based, and the limitations and uncertainties of the chosen models, and the bases for excluding alternative models.

- Verify that the models used in the performance assessment adequately represent or bound the uncertainty associated with underlying process-level models, if applicable. Where appropriate, use a detailed auxillary analysis (i.e., an analysis performed outside of the overall performance assessment analysis) to verify that the DOE performance assessment approach reflects or bounds the uncertainties in the process-level models.

- The reviewer should verify that the selected conceptual model is conservative relative to alternative models that are consistent with available supporting information.

- Verify that quantitative evaluation of model uncertainty included the impact of data uncertainty in alternative models.

4.2.5 Model Support Review Procedure

- Evaluate the output from the performance assessment, and verify that DOE has compared the results with an appropriate combination of site characterization and design data, process-level modeling, laboratory testing, field measurements, analogs, and formal independent peer review.

- Examine the output from the mathematical models for consistency with the description of the conceptual models.

- Verify that the performance assessment model is reasonably supported by observations from the site, if available. For example, compare the output from the DOE performance assessment with inferences about fate and transport of radionuclides in the environment developed from data for leaks, spills, and environmental monitoring.

- Verify adequate justification and technical bases exist that simplified model outputs adequately represent or conservatively bound process-level model outputs. For example, if DOE uses a simplified model to predict barrier performance, verify that the abstracted model is shown to bound process-level model predictions.

- Where appropriate, use independent analyses to evaluate selected parts of the DOE performance assessment model and assess whether the resulting doses are comparable.

- If possible, perform simplified calculations of processes and compare to the intermediate outputs of the performance assessment models. For example, estimate the ground water travel time of select radionuclides using information on gradient, hydraulic conductivity, porosity, density and distribution coefficient and compare to the travel times generated with performance assessment models.

- Confirm that DOE has identified and implemented adequate procedures to construct and test its mathematical and numerical models.

4.3 Specific Technical Review Procedures

In contrast to the general review procedures presented in the previous section, this section provides detailed review procedures that are specific to the different technical areas comprising component models of the DOE performance assessment. These review procedures were developed from experience developed in prior reviews, and may be enhanced, modified, or supplemented based on future experience. As previously discussed, a performance assessment model may be a manually-integrated or fully-automated collection of individual models representing specific technical areas and processes. The individual models are commonly referred to as component models, process models, submodels, or abstractions. This terminology is used interchangeably in the specific review procedures that follow. The submodels are presented in a "top-down" sequence that is similar to that described in NUREG-1573 (NRC, 2000). Not all of the specific technical review procedures will be applicable to every waste determination, and the level of review should be adjusted to reflect the significance of a given component (e.g., infiltration, engineered barriers) to system performance (see Section 4.6).

It is expected that DOE will have a fairly large collection of technical reports for a variety of activities that have occurred at the sites over the years. For example, hydrogeologic studies and models may have been completed or developed for management of existing contamination or to evaluate the performance of other disposal facilities for radioactive waste at the DOE site. To the extent practical, the reviewer should consider other sources of information that may support or refute the models and analysis used in the waste determination. For example, the observed transport of Cs-137 from a waste disposal facility for LLW at the DOE site may support or refute the use of various values of K_d from a generic literature source used in the waste determination.

4.3.1 Climate and Infiltration

4.3.1.1 Areas of Review

This section focuses on the models and data that support climate projections, infiltration, and unsaturated zone flow estimates used in DOE waste determinations and the performance assessment supporting the waste determinations. Temporal and spatial variations in processes and parameters related to climate, infiltration, and unsaturated zone flow are potentially important to system performance because one of the primary mechanisms of release of radioactivity from a disposal facility is in the water pathway. It is important to make a distinction between infiltration (that part of precipitation which moves past the root zone) and water flow in the unsaturated zone (deeper flow whether through soil, rock, or anthropogenic fill material). Infiltration can affect engineered barrier performance and the release of radionuclides (see Section 4.3.2). Unsaturated zone flow is a function of the physical characteristics of the unsaturated zone and the rate and distribution of infiltration input to the unsaturated zone (e.g., boundary and initial conditions). Unsaturated zone flow affects the transport of radionuclides to the saturated zone.

4.3.1.1.1 Current Meteorology and Precipitation at the Site

The amount of water that contacts the waste is an important factor for estimating the release of radionuclides from a waste disposal facility. Knowledge of local meteorology and precipitation is necessary to estimate infiltration and the potential for water to contact the waste. Current information provides a baseline against which to evaluate the significance of any potential changes over the period of performance (see Section 1.1.3).

Meteorological information is typically an input to calculations or models used to estimate infiltration. The reviewer should evaluate information on precipitation (duration, intensity, frequency, and seasonal variations of precipitation events), local air temperatures (daily and seasonal variations), wind speeds and directions, and air humidity levels.

4.3.1.1.2 Current Infiltration and Unsaturated Zone Flow at the Site

The disposal horizon at most sites is located above the local water table in the hydrologically unsaturated zone, sometimes also referred to as the vadose zone. Precipitation at a site can follow several paths. Depending on the topography of the site and the composition of the topmost soil or cover materials, water may tend to pond in some areas or to run off. Some water may penetrate only the topmost layer of soil where it may be evaporated directly to the atmosphere or be taken up by plants and then transpired back into the atmosphere.

Some fraction of the precipitation may move below the zone of evapotranspiration and contact engineered barriers or other portions of the disposal system. This fraction is infiltration. Flow of infiltration through the unsaturated zone will be affected by heterogeneities, fractures, anthropogenic changes and features that may lead to faster and preferred water pathways (e.g., abandoned boreholes and wells). The amount of water that moves to the disposal horizon, the frequency of the flow, and the spatial distribution of the flow are all potentially significant factors to performance of the waste disposal facility. If waste is located below the water table, then saturated zone flow would control the amount of water contacting the waste. Water contact would be limited by the engineered barriers and related engineered systems.

The reviewer should evaluate the information on local soils and rocks that affect infiltration and unsaturated zone flow (e.g., hydraulic conductivity, porosity, moisture content), vegetation (types, distributions, seasonal changes), topography, erosion, runoff and drainage, and the potential for flooding or ponding. The reviewer should examine the seasonal variation in the independent variables for modeling infiltration and resultant unsaturated zone flow. For example, in colder climate sites, a significant fraction of annual infiltration may result from snow melt or similar processes when evapotranspiration is low. For modeling unsaturated zone flow, DOE should provide properties (e.g., moisture characteristic curve parameters) that are supported by empirical measurement or are sufficiently conservative (if generic information is used). The reviewer should examine information provided on the spatial variability of features and properties, or the approach to address spatial variability. The reviewer should evaluate the model support for estimates of unsaturated zone flow. Because unsaturated zone flow is generally inherently more uncertain than saturated zone flow, a commensurate amount of increase in the model support or the conservatism of the analysis should be expected.

Information should be provided regarding the potential for perched zones to affect flow and transport. If perched zones affect flow and transport, the location, extent, and persistence of the perched zones should be supported by monitoring data. Changes in operation that may affect perched zones (e.g., use of percolation ponds) should be evaluated. If the perched zones are important, the reviewer should determine if DOE has evaluated the relative contribution to the extent of the perched zones from both natural (e.g., recharge) and anthropogenic sources.

4.3.1.1.3 Projected Meteorology and Precipitation at the Site

The reviewer should evaluate the current information on the meteorology and precipitation at the site. The reviewer should also evaluate paleoclimatic information for the site. Recent and current climate data are the best available predictors of the near-term future conditions at the site whereas paleoclimate data may provide a basis for interpreting potential future changes in the climate. It is important to assess the assumptions made by DOE in extrapolating the past and current information to project those values and patterns into the future. For example, climate changes may be assumed to be cyclical or linked to orbital patterns (e.g., Milankovitch forcing). Climate projections should cover the full duration of the performance period. The reviewer should examine information presented as to how uncertainties inherent in projections of future climate have been accounted for and how those uncertainties have been propagated through the performance assessment, as appropriate.

4.3.1.1.4 Projected Infiltration and Unsaturated Zone Flow at the Site

In general, site conditions are expected to change somewhat over long time periods and to result in changes to infiltration at the site. Changes to infiltration will produce changes in the unsaturated zone flow. The reviewer should evaluate the available information on infiltration at the site to project infiltration rates and distributions into the future. These projections should cover the full duration of the performance period. Infiltration projections should account for any construction or engineered features (see Section 4.3.2) that are designed to control or reduce infiltration (e.g., caps, drainage layers, geosynthetics, etc.), or other changes to site conditions that may affect infiltration (e.g., variations in precipitation, vegetation or soil cover caused by erosion). The reviewer should evaluate the integration of infiltration and water flow in the unsaturated zone, if computed by different models. In reviewing infiltration barriers, the reviewer should evaluate any credit taken for maintenance or long-term performance of these barriers after the loss of institutional controls. The relationship between projected precipitation and projected infiltration should be described. Projections of infiltration should take into account the uncertainties inherent in such estimates and should propagate those uncertainties through the performance assessment, as appropriate. Infiltration at semi-arid sites is generally controlled by short-duration (i.e., hourly or daily) storm events. Thus, estimates of infiltration based solely on long-term (i.e., monthly or yearly) precipitation and evaporation rates at a semi-arid site may be misleading.

4.3.1.2 Review Procedures

To review this performance assessment submodel, the reviewer should consider the degree to which DOE relies on climate and infiltration to demonstrate compliance with 10 CFR 61.41, considering available sensitivity analyses, uncertainty analysis, and barrier or component analysis (see Section 4.6). For example, the reviewer should perform a detailed review of this area if DOE relies on estimates of infiltration that are significantly lower than natural recharge values and that correspondingly produce lower release rates and provide significant delay in the transport of radionuclides. If, on the other hand, DOE demonstrates this submodel to have a minor impact on release rates or the transport of radionuclides to the receptor, then conduct a simplified review focusing on that the analysis has been appropriately implemented. In general, higher infiltration rates will result in higher dose estimates, because there will be resulting higher mass flux rates of contaminants to the saturated zone and higher recharge rates to the saturated zone, and the overall dilution in the calculation will be dominated by the saturated zone modeling. In a risk-informed, performance-based review, some of the following review procedures may not be necessary when conducting a simplified review for those models that have a minor impact on performance:

- Apply the general review procedures found in Section 4.2 to the assessment of infiltration and unsaturated zone flow.

- Confirm that an adequate baseline for current meteorology and precipitation at the site has been used. The reviewer should evaluate the adequacy of information on precipitation (duration, intensity, frequency, and seasonal variations of precipitation events), local air temperatures (daily and seasonal variations), wind speeds and directions, and air humidity levels.

- Evaluate engineered features (see Section 4.3 of this review plan) that are designed to control or reduce infiltration (e.g., caps, drainage layers, geosynthetics), or other changes to site conditions that may affect infiltration (e.g., variations in vegetation or erosion of soil cover). In reviewing these infiltration barriers, the reviewer should also evaluate any credit taken for maintenance during the institutional control period or long-term, passive performance of these barriers after the loss of institutional controls.

- Examine the relationship between infiltration and the water table elevation over time for those disposal sites near the water table.

- Evaluate information regarding the potential for perched water zones to affect flow and transport. Activities that may affect perched zones (e.g., use of percolation ponds) should be evaluated. If perched zones are important to the performance of the site, the reviewer should determine if DOE has adequately evaluated the relative contributions to the extent of the perched zones from both natural and anthropogenic sources.

- Verify that the data for infiltration are at appropriate time- and space-scales. Confirm that adequate site-specific climatic, surface, and subsurface information is used.

- Confirm that precipitation estimates are based on long-term precipitation data that are adequately representative of the disposal facility location on the site. Long-term data for precipitation are typically considered to extend over a period of several decades to 100 years.

- Verify, if estimates of infiltration are based on modeling, that the analysis has considered seasonal variation in independent variables and short duration, large magnitude events, especially when discrete high-permeability pathways that can transmit large amounts of infiltration are present in the near-surface (e.g., dessication cracks in a clay soil).

- Where applicable, confirm that adequate representation of the effects of fracture properties, fracture distributions, matrix properties, heterogeneities, time-varying boundary conditions, evapotranspiration, depth of soil cover, and surface-water runoff and run-on is incorporated in the model or calculation.

- Confirm if uncertainty in data, because of both temporal and spatial variations in conditions affecting climate and infiltration, is incorporated into the selection of deterministic parameters or the definition of parameter ranges. For example, the review should evaluate the climatic and hydrostratigraphic parameters used in the model to verify that they are consistent with site characterization data and sufficiently detailed to capture heterogeneities that may influence the distribution and rate of liquid-water flux that has moved beyond the zone of evapotranspiration (infiltration and unsaturated zone flow).

- Evaluate the assumptions used by DOE to extrapolate from past climate data to future climate conditions. For example, the reviewer should determine whether climate changes are assumed to be cyclical or are linked to orbital patterns (e.g., Milankovitch forcing).

- Verify whether climate projections cover the full duration of the performance period and determine if uncertainties in the projections are adequately accounted for and propagated through the performance assessment.

- Confirm that the performance assessment incorporates the hydrologic effects of future climate change that could alter the rates and patterns of present-day infiltration into the unsaturated zone.

- Ensure that infiltration estimates are either chosen in a clearly conservative manner, or are supported by multiple lines of evidence. Typically, higher infiltration rates are more conservative, although in some circumstances a higher infiltration rate could result in a lower dose (e.g., dilution in perched water zones).

- Ensure that appropriate model support is provided for infiltration rates (e.g., infiltration rates are consistent with: calibrated recharge rates from large-scale or regional flow models, other calculated values, infiltration rates from other site estimates, soil properties).

- Because some DOE sites can be quite large, if site-specific infiltration rates developed or measured from other areas on the site are used to support the estimates for the waste disposal facility, confirm that they would be expected to be reasonably representative of local estimates for the waste disposal facility based on similarity of important variables (e.g., soil type, topography, vegetation).

- Ensure that the estimates of infiltration and unsaturated zone flow have appropriately considered anthropogenic features or actions at the site. For example, an undisturbed soil profile may have an infiltration rate that is different from that for a disturbed soil.

- Ensure that the parameters used by DOE to model unsaturated zone flow are supported by empirical measurements, or that generic information sources are sufficiently conservative. The reviewer should confirm that parameter selection considered spatial variations in the properties of the materials.

- Determine that the impact of fractures or other naturally-occurring discrete pathways have been represented in the modeling of flow in the unsaturated zone, if applicable. The reviewer should ensure that the potential effects of preferential pathways have not been underestimated by the selected model.

- Determine that adequate model support is provided for unsaturated zone flow (e.g., field-scale observations or measurements, evaluation of the transport of past leaks or spills) consistent with its risk significance. If a unit gradient approach is not adopted, ensure that adequate model support is provided to justify a less conservative approach.

4.3.2 Engineered Barriers

A wide variety of engineered barriers may be employed for incidental waste disposal, depending on the nature of the waste and the planned disposal environment. Engineered barriers are anthropogenic structures or devices intended to improve the disposal facility's ability to meet the performance objectives in 10 CFR Part 61, Subpart C (10 CFR 61.2). In this document the term "engineered barrier" includes those anthropogenic barriers such as tanks, vaults, and other components and systems that limit release of waste to the accessible environment (e.g., grout, infiltration caps, erosion protection covers, slurry walls) or limit inadvertent intrusion. In the performance assessment modeling, DOE may decide not to take credit for all engineered barriers present at the site. Each type of engineered barrier will have a timeframe over which it will be designed to perform its intended functions (e.g., the design life), which should be justified for the specific application of the barrier. There is significant uncertainty in the ability of engineered barriers to achieve the design goals when extrapolated over long periods of time, and the uncertainties tend to increase with increasing performance periods. An engineered barrier with design goals significantly in excess of relevant experience (either in degree or duration) should have a commensurately higher amount of model support that the barrier will likely achieve the design goals. Regardless of the model support, analysis should be performed to understand the impacts if the barrier does not achieve its design goals.

4.3.2.1 Areas of Review

This section focuses on the engineered barriers proposed by DOE in its waste determination and performance assessment. Improvement in the performance of the disposal facility can be achieved by limiting the amount of water that contacts the wasteform, reducing the transport of radionuclides within and from the site, and providing shielding from direct exposure, among other functions. In particular, the review should focus on those aspects of the engineered barriers that are most critical to meeting the performance objectives in 10 CFR Part 61, Subpart C. Section 4.6 provides guidance to evaluate the risk significance of barriers to estimating performance of the disposal facility.

4.3.2.1.1 Features and Dimensions of the Engineered Barrier System(s)

The reviewer should evaluate the descriptions of the engineered barriers proposed for the site. The description of the engineered barriers will typically include the geometry, dimensions, materials, functionality, design goals, and pertinent degradation mechanisms. Engineered barriers may be above-grade or below-grade, and may be physical (e.g., vaults, covers, erosion control barriers, drainage systems, containers, backfill, or infill) or chemical (e.g., pH buffers, oxygen getters). Radionuclide mobility through engineered barriers may be affected by the physical state of the barrier (e.g., low permeability and porosity) and chemical phenomena such as sorption, precipitation, coprecipitation, dissolution, and ion exchange. The reviewer should evaluate the potential for the physiochemical conditions produced by the barriers to limit radionuclide mobility (e.g., by limiting flow and maintaining reducing water compositions).

The reviewer should examine the design for the waste disposal system. The design should specify the dimensions, spatial relations, and compositions of the engineered barriers. Specifically, the reviewer should examine figures and illustrations (e.g., cross-sections that illustrate the components of the engineered barrier system). Those portions of the design for which DOE takes credit as engineered barriers should be identified. The reviewers should examine the design functionality (e.g., limit water contact with the waste, limit erosion) and properties of the engineered barriers (e.g., porosity, hydraulic conductivity, sorption coefficients). The reviewer should evaluate the design goals and the description and analysis of pertinent degradation mechanisms to verify that the engineered barrier will likely be able to achieve the design goals.

4.3.2.1.2 Performance of Engineered Barriers

The effectiveness of engineered barriers, such as engineered caps and reducing grouts, is expected to diminish over long time periods. Combinations of physical and chemical processes will result in changes to the original barriers that may reduce their effectiveness (e.g., formation of cracks in grout, concrete, or clay). The reviewer should examine the assumptions of barrier degradation and the justification and technical bases for the time period for which DOE takes credit for the effectiveness of the barriers.

For engineered barriers, such as engineered caps that are designed to reduce infiltration through the wasteform, the reviewer should evaluate the technical basis used to support estimates of physical durability with time. Conceptual models (e.g., of fracturing of a cap or wasteform that may impact the physical durability) should be supported by test results that are appropriate for the materials to be used in the barrier. Because of the long time periods involved, the reviewer should also evaluate information provided on the impact of biointrusion (e.g., root penetration, burrowing animals) on engineered barrier performance.

The reviewer should evaluate the technical basis provided to support DOE estimates of the chemical performance of engineered barriers and wasteforms (e.g., reducing grout, saltstone) during the performance period. For example, for a reducing cementitious wasteform the reviewer should examine the analysis of the effects of temporal changes in pH and redox in engineered materials (such as concrete) on source term K_d values which may determine the release rates of radionuclides. The persistence of the chemical durability of a barrier may be directly related to the physical properties of the barrier. Information should be provided for the reviewer to evaluate the coupling of physical and chemical degradation mechanisms of barriers.

For erosion control barriers (see Section 7), the reviewer should consider rock durability, gradation, cover design, stability calculations for the top slope, side slope, and apron for any cover, and other construction considerations that are important to the performance of the erosion control system.

4.3.2.1.3 Integration and Interaction of Materials

The assessment of the effectiveness of each engineered barrier may need to consider the interaction with and among other engineered barriers that may be employed (e.g., durability of a cement barrier may be affected by corrosion of an exposed steel liner that transects the cement barrier).

The reviewer should evaluate the compositions of the materials proposed for the engineered barriers, the spatial relationships among the materials, and potential interactions among the engineered materials and with the natural system. For example, the amount of water that penetrates the engineered barriers, the composition of the penetrating water, and the composition of the water after interaction with the engineered barriers and wasteforms will affect the leaching of radionuclides from the wasteforms and the near-field transport of radionuclides.

4.3.2.1.4 Construction Quality and Testing

The reviewer should examine the parameters chosen to represent the engineered barriers in the performance assessment and compare those parameters to the quality requirements for the design and test results of the engineered barriers. Selection of deterministic parameters or parameter distributions should account for expected variability in materials, construction implementation, and other uncertainties (e.g., interactions among materials and with the natural system; the properties of as-emplaced materials). The reviewer should evaluate tests or measurements used to support parameter values implemented in the performance assessment (e.g., permeability and hydraulic conductivity testing). The reviewer should evaluate information or the plans to develop information to demonstrate that as-emplaced properties are consistent with laboratory-measured or design values.

4.3.2.1.5 Modeling of Engineered Barriers

The objective of engineered barrier analysis is to establish model representations of the physical dimensions and characteristics of designed engineered features, and to determine the ranges of parameter values that would reasonably represent the behavior of the features with the passage of time (NRC, 2000). In developing the performance assessment model for the engineered barriers, DOE should present a design concept that includes information on spatial relationships among physical components (e.g., the layout and physical dimensions of a vault or cover system) and the physical distribution of various types of materials that are used in the facility. Not all design features will necessarily be reflected in the performance assessment as engineered barriers, but DOE should identify and include those components (e.g., engineered caps) and associated materials (e.g., reducing grout) that are most important to demonstrating compliance with the performance objective. The reviewer should examine those components and materials identified by DOE, and evaluate how they are represented in the performance assessment modeling of the engineered barriers.

The reviewer should evaluate the degradation mechanisms associated with the engineered barriers. Barriers may degrade from internal (e.g., interaction between incompatible materials, interaction with the waste) or external processes (e.g., interaction with biota, erosion, leaching by infiltrating water, disruptive processes such as seismically induced cracking). Analysis of a barrier system should be performed in an integrated manner because of the potential synergism between degradation mechanisms. If the analysis is performed assuming the degradation mechanisms are independent, the reviewer should evaluate the information to determine adequate basis is provided for the analysis approach (e.g., assuming the degradation mechanisms can be evaluated as being independent), which may include providing information to demonstrate that the degradation analysis was reasonably conservative.

The reviewer should evaluate how DOE has considered the interaction of the components of the engineered system and materials in the engineered barrier system. Factors that may need to be considered include: (1) compatibility among materials that may come in contact with each other; (2) the manner in which construction may affect system behavior (e.g., construction joints, changes in geometry, penetrations); (3) the effect that failure of a design feature or some portion of an engineered barrier would have on the overall behavior of the system; and (4) how the degradation of material properties affects barrier performance over time (NRC, 2000). The DOE performance assessment should include consideration of relevant materials and conditions that could affect release from the waste disposal system, over the service life of the engineered barriers.

The reviewer should evaluate information that DOE uses to support the model estimates of engineering barrier performance. This may include site-specific test information, previous experience with similar systems, process modeling of barrier component performance (e.g., detailed models of an infiltration cap), field studies, natural analogs, independent peer review, or additional sources of relevant information. DOE may also use preliminary analyses to assess the need for additional performance enhancements that may, in turn, dictate the use of improved or additional engineered barrier systems (e.g., the performance modeling of reinforced concrete vaults, soil covers). In this manner, design features and engineered barriers would evolve from important conclusions developed with initial performance assessment results. Information from these types of analyses may be factored into monitoring activities (see Section 10).

4.3.2.2 Review Procedures

To review models of engineered barriers, consider the degree to which DOE relies on engineered barriers and near-field radionuclide transport to demonstrate compliance with 10 CFR Part 61, Subpart C, and the contribution of the engineered barriers to system performance (see Section 4.6). For example, if DOE relies on the engineered barriers to provide significant reduction in the mass flux of waste from the disposal system compared to that provided by the waste and natural system, then perform a detailed review of the modeling. On the other hand, if DOE demonstrates the model to have a minor impact on the dose of the receptor, then conduct a simplified review focusing on determining that the calculations of barrier performance have been appropriately implemented in the performance assessment. In a risk-informed, performance-based review, some of the review procedures may not be necessary when conducting a simplified review for those models that have a minor impact on performance. The reviewer should perform the following procedures:

- Apply the general review procedures found in Section 4.2 to the assessment of engineered barrier performance.

- Evaluate the descriptions of the engineered barriers proposed for the site and determine that the descriptions adequately describe the physical and chemical characteristics of the barriers.

- Confirm that the design for the engineered barriers adequately provides the dimensions, spatial relations, and compositions of the barriers. Specifically, the reviewer should examine figures and illustrations (e.g., cross-sections that illustrate the components of the engineered barrier system).

- Assess whether the descriptions of the engineered barriers include adequate detail on the design features, the functionality (e.g., ability to limit water contact with the waste), and properties (e.g., porosity, hydraulic conductivity, sorption coefficient) of the barriers.

- Verify that an adequate description of the materials and methods used to construct the engineered barriers has been provided.

- Ensure that the description of degradation mechanisms and physical and chemical phenomena that may affect the degradation of the engineered barriers is clear, complete, and any synergisms between mechanisms are provided. For example, degradation mechanisms for a cementitious barrier may include sulfate attack, carbonation, freeze-thaw, cracking (e.g., shrinkage, seismic-induced), reinforcement corrosion, leaching, and exposure to cyclic wetting and drying.

- Examine the assumptions about how the barriers will degrade and the justification and technical bases for the time period for which DOE takes credit for the effectiveness of the barriers.

- Verify that mathematical models for the degradation of engineered barriers and near-field transport of radionuclides are based on similar environmental parameters, material properties, and assumptions.

- Evaluate the technical bases used to support estimates of physical durability of engineered barriers with time. For example, the reviewer should ensure that conceptual models for fracturing of a wasteform or clogging of a drainage layer in an engineered cap are supported by test results that are appropriate for the materials used in the barrier.

- The reviewer should evaluate the technical bases provided by DOE to support estimates of the chemical performance of engineered barriers and wasteforms (e.g., reducing grout, saltstone) during the performance period.

- Ensure that DOE has evaluated potential changes in pore water chemistry (e.g., pH, redox) with time, taking into account the amount of water expected to pass through the wasteform and the proposed grout formulation (e.g., novel ingredients, cement fraction).

- Ensure that DOE has adequately considered the potential for oxidizing conditions in the disposal system (e.g., oxidation by aqueous or gaseous transport into the wasteform or oxidation of engineered materials by interaction with the waste).

- Evaluate the potential for the physicochemical conditions produced by the barriers to limit radionuclide mobility (e.g., by maintaining reducing water compositions).

- Evaluate the impacts of biointrusion (e.g., root penetration, burrowing animals) on engineered barrier performance, and if appropriate verify that the impacts have been appropriately represented in the performance assessment modeling.

- Evaluate the compositions of the materials proposed for the engineered barriers and potential interactions among the materials and with the natural system.

- Examine the parameters chosen to represent the engineered barriers in the performance assessment. The reviewer should compare those parameters to the quality requirements for the design and to the results of tests or measurements of the properties of the engineered barriers.

- Evaluate any testing used to support parameter values used in the performance assessment (e.g., permeability and hydraulic conductivity testing) and determine whether the test conditions were representative of the expected environmental conditions for the barrier, and that tests results have been interpreted appropriately (e.g., that leach test results have been corrected for changes in surface area to volume ratios).

- Examine the engineered barrier components and materials identified by DOE and evaluate how they are represented in the performance assessment of the engineered barriers.

- Evaluate how DOE has modeled the engineered barrier components in the performance assessment. The reviewer should examine modeling of interactions between materials, construction effects (e.g., joints, penetrations), potential effects of failure of design features, and degradation of material properties over time.

- Evaluate the parameters used to describe flow through and out of the engineered barriers, and confirm that they are sufficient to bound the flow through the barriers.

- Evaluate information DOE uses to support the engineering barrier analysis. The reviewer should examine any site specific testing, information on previous experience with similar systems, process modeling of barrier component performance (e.g., detailed modeling of an infiltration cap), natural analogs, independent peer review, or plans to develop additional model support for engineered barrier system performance.

4.3.3 Source-Term/Near-Field Release

The modeling of the source term can be one of the most important determinants of the overall disposal facility performance. Source term modeling is used to estimate the partitioning in and release of radionuclides from the disposal unit. Releases generally occur by advective or diffusive mechanisms, although direct release mechanisms may be possible (e.g., biointrusion, erosion). The near-field is generally defined as the area surrounding the waste that may have moisture flow and chemical conditions (e.g., due to the presence of the waste or engineered barriers) significantly different from the natural system in which the waste disposal facility is located.

The objective of source term analysis is to calculate radionuclide releases from the disposal facility as a function of space and time. These radionuclide release rates can then be used as input for transport models that estimate offsite releases from the facility. Radionuclides are typically released from the waste or wasteform and transported in the aqueous phase, but release of certain radionuclides (e.g., C-14, H-3, Kr-85) can occur in the gaseous phase. Although liquid releases can be significantly constrained by considerations of the flux of water entering a disposal unit, gaseous releases are relatively unconstrained because of the significantly higher rates for gaseous diffusion and advection compared with diffusion and advection of radionuclides in the liquid phase. Gaseous advection and diffusion may become limited at high liquid saturations. Gaseous and liquid releases will often be analyzed separately in performance assessment analyses because of the significant differences in the nature of the releases, and because in many cases the limited inventory associated with the gaseous release and limited resultant impact on performance readily lends itself to a simple bounding analysis.

4.3.3.1 Areas of Review

This portion of the review is focused on the assumptions, data, and models (conceptual and computational) used by DOE to develop the source term for the performance assessment model. Source-term analyses are conducted to calculate releases of radionuclides as a function of time and space. The release rates are used as inputs to radionuclide transport models. The complexities of most sites and proposed disposal approaches usually result in source-term analyses being developed on a site-specific basis. Source term modeling is commonly implemented in performance assessment models with a simplified representation of the distribution of the radionuclide inventory and physiochemical processes associated with the partitioning of radionuclides between the materials and physical phases in the disposal unit. The simplified representation is abstracted for inclusion in mathematical and computer model representations of the real system. The source-term model should include the effects of the degradation of the wasteform and the engineered barriers, as appropriate. For example, cracking of a grouted wasteform over time may lead to advective release, rather than diffusive release. In another example, chemical barriers such as reducing grout formulations may lose their effectiveness over time, and the release models used in the source-term analysis should reflect these temporal changes to the disposal facility.

Representing the source term in a performance assessment involves generalization of the details of the system into more simplified conceptualizations that can be modeled. Whereas the source-term abstractions must adequately represent the features and processes significant for disposal system performance, it is important that the abstractions do not simplify system behavior to the extent that disposal system performance is significantly underestimated or unrealistically overestimated.

4.3.3.1.1 Inventory of Radionuclides in Waste

The inventory of radionuclides in the waste is used to assess the removal of highly radioactive radionuclide to the maximum extent practical (see Section 3) and the concentration limit criteria related to 10 CFR 61.55 (whether the waste exceeds the concentration limits for Class C waste) (see Section 3.5). The inventory also provides the radionuclide inventory for which release rates are estimated with source-term calculations. The radionuclide inventory evaluated in this portion of the review should be consistent with radionuclide inventory used in the assessment of compliance with the site-specific radionuclide removal and concentration limit criteria described in Section 3 of this review plan.

The reviewer should evaluate the description of the radionuclide inventory in the waste. All radionuclides (particularly highly radioactive radionuclides) should be described by volume, concentration, and location within the disposal system. Radionuclides with relatively high solubility, low sorption, and high dose conversion factors and/or significant ingrowth are of particular significance. Additional detailed guidance for reviewing radionuclide inventory is provided in Section 3.1 of this review plan.

4.3.3.1.2 Degradation and Release From Wasteforms

The reviewer should evaluate the descriptions of the wasteforms and the representation of the wasteforms in the source-term modeling. Waste is almost exclusively stabilized in a solid form to reduce its mobility and dispersibility into the environment. Wasteforms can be of a variety of types, including cement-solidified waste, activated metal, glass, bulk waste, and others. Wasteforms limit aqueous and gaseous releases once the engineered barriers degrade. Different wasteforms will have different release processes and degradation mechanisms. For example, a high-quality cement-solidified wasteform may be dominated by diffusional release, whereas a glass wasteform may release radionuclides mainly by dissolution of the glass matrix. In addition, the release mechanisms may change during the period of performance (e.g., while diffusion may dominate release from high-quality, intact cementitious wasteforms, advection may dominate release from degraded or lower-quality cementitious wasteforms). These differences can be very important in evaluating the appropriateness of source-term models.

The reviewer should evaluate the wasteform degradation processes considered by DOE and evaluate how they are incorporated in the source-term model. The wasteform degradation modes may include leaching, dissolution, and chemical reactions with groundwaters. Performance of the wasteform may be reduced by chemical changes such as sulfate attack or carbonation, or by physical changes such as cracking caused by settling or seismic activity and damage by reinforcement corrosion. Degradation of the wasteform can increase penetration of groundwater into the waste and can provide shortened and more permeable paths for release of radionuclides. Degradation can also change the type of mechanisms that dominate release from the wasteform (e.g., cracking may enhance advective release).

4.3.3.1.3 Source-Term Models

The reviewer should evaluate the source-term models used. Source-term models are ultimately used to estimate release rates from the disposal facility, but may include estimation of many intermediate processes in the calculation of release rates. Release rates can be affected by the performance of engineered barriers, as well as the specific physical and chemical properties of the disposal system and the interaction of the disposal system with the natural environment (e.g., porewaters that are high in magnesium may have an effect on cement performance). Some disposal plans will require detailed consideration of these processes and conditions whereas simplified analyses may be justified for other sites and disposal options. Sites for which the source term models need to be considered carefully are sites for which there is significant credit taken for some aspect of the source term modeling (i.e., low solubility limits) and for which there may not be very strong model support. Sites for which a simpler analysis is acceptable are sites for which the simple analysis can be shown to be clearly conservative or for which the simple model is well-supported by multiple lines of evidence, including field testing that shows the simple model accurately represents or bounds field results. The information reviewed as part of the evaluation performed for Section 4.6 should help focus the reviewer on the key aspects of the disposal facility performance and should provide the reviewer with information to determine the importance of source-term modeling and near-field release.

There are generally four categories for aqueous radionuclide releases: (1) rinse release, (2) diffusional release, (3) dissolutional release, and (4) partitioning release. Rinse release refers to washing of radionuclides from the surface of a wasteform by infiltrating groundwater. Diffusional releases occur when radionuclide movement through a porous wasteform (e.g., a cement-stabilized wasteform) is limited by diffusion. Radionuclide release resulting from corrosion of an activated metal or dissolution of glass wasteforms are examples of dissolutional release. Partitioning release results when radionuclide release is described by a characteristic distribution coefficient (K_d) or other parameter which distributes activity between phases in the system (e.g., between the wasteform and liquid contacting the wasteform). Solubility limits may be very important in estimating release rates with source term models, particularly for extreme chemical environments (e.g., high pH associated with pore fluids of cementitious wasteforms or cementitious engineered barriers).

4.3.3.1.4 Chemical Environment

The reviewer should evaluate the chemical environments of the system. There may be spatial variation in the chemical environments within the system, and they may also change over time. The reviewer should evaluate the chemical environment for consistency with the degradation of wasteforms and engineered barriers that may affect the chemical environment (see Section 4.3.3.1.2). The chemical environment may be important to defining the lifetimes of engineered barriers. The chemical environment is important to estimating radionuclide release from the wasteform, and the transport of released radionuclides within and from the disposal facility. The chemical environment is particularly important if DOE relies on solubility limits or retardation of radionuclides within the disposal unit to satisfy the performance criteria. The site-specific chemical environment of a disposal facility may include engineered components designed to have chemical properties that will enhance performance.

4.3.3.1.5 Gaseous Releases

The reviewer should evaluate the potential for gaseous releases because some radionuclides may be released in a gaseous form (e.g., carbon-14, tritium). The timing and rate of a gaseous release will depend on the design of the engineered barrier. After release from the engineered barrier, gaseous radionuclides can move by advection and diffusion through any overlying soil or other materials to reach the atmosphere, where they will be transported in the atmosphere. Some gaseous releases may interact with components of the soil and groundwater and are not strictly controlled by advection and diffusion. Gaseous releases are likely to have limited impact on most waste determinations due to limited inventory and can be handled by relatively simple bounding calculations (e.g., a box model). The reviewer should evaluate assumptions regarding the effects of saturation on diffusivities and chemical and biological retention.

4.3.3.2 Review Procedures

Review the source-term modeling considering the information on the importance to disposal facility performance presented in Section 4.6. If DOE relies on the source term to significantly reduce or mitigate radiological impacts, then perform a detailed review of the source-term modeling. If, on the other hand, DOE demonstrates that this abstraction has a minor impact on the dose, then conduct a simplified review focusing on determining that the calculations have been properly implemented in the performance assessment model. The reviewer should evaluate the consistency of information provided for the source-term with information provided on engineered barrier systems (Section 4.3.2) and on climate and infiltration (Section 4.3.1). The reviewer should verify that source-term modeling has been appropriately integrated with other models in the performance assessment. In a risk-informed, performance-based review, some of the review procedures may not be necessary when conducting a simplified review for those models that have a minor impact on performance. The reviewer should perform the following procedures:

- Apply the general review procedures found in Section 4.2 to the modeling of source term and near-field release.

- Evaluate the description of the radionuclide inventory in the waste. The reviewer should confirm that radionuclides are described by volume, concentration, and location within the disposal system. Information evaluated should be consistent with that considered under Section 3.1 of this review plan.

- Examine the description of the wasteform and verify that the implementation of the wasteform in the source term modeling for the performance assessment is consistent with the description.

- Examine the DOE description of environmental conditions expected inside failed engineered barriers and within the disposal facility environment surrounding the engineered barriers. Verify that the ranges in conditions are described in sufficient detail.

- Evaluate potential changes to the chemical environment of the disposal system over time and resulting changes in degradation of the engineered barriers and wasteforms that may affect the source term and near field transport. Verify that these potential changes are consistent with the information on engineered barrier performance in Section 4.3.2 of this review plan.

- Evaluate radionuclide release testing programs relied upon by DOE for the wasteforms and other sources of data supporting the durability of and release rates from the wasteforms. Verify that the programs or data sources provide sufficient and suitable data for use in the source-term abstraction. Evaluate the justification for the use of test results not specifically collected from the site of interest.

- Evaluate the parameters used to describe flow through and out of the wasteform, and confirm that they are sufficient to bound the flow through the wasteform.

- Evaluate the potential for gaseous releases of radionuclides. Verify that potential gaseous releases are consistent with the design of the engineered barriers evaluated in Section 4.3.2.

- Evaluate assumptions regarding the effects of saturation on diffusivities and chemical and biological-mediated attenuation of potential gaseous releases.

- Verify that DOE has adequately considered the uncertainties in the characteristics of the natural system and engineered materials (e.g., the type, quantity, and reactivity of material) in establishing initial and boundary conditions for conceptual models and simulations of processes that affect the source term.

- Confirm that DOE has considered a range of wasteform degradation mechanisms that are appropriate to the wasteform design and the physical and chemical conditions of the disposal environment.

- Confirm that data used to support the release rates are representative of the range of composition of the wasteform and the range of chemical conditions of the disposal environment.

- Ensure that changes in release mechanisms that could occur because of degradation of the engineered barriers are appropriately accounted for (e.g., advective versus diffusive release from degraded wasteforms).

- Ensure that moisture characteristic curve parameters used for near-field release modeling are supported by empirical measurement or if generic information is used, it is sufficiently conservative.

- Ensure that K_d and solubility limit parameters used in the release model accurately reflect the material and chemical environment of the wasteform (e.g., literature values relevant to ordinary cement may not be relevant to novel grout formulations). The reviewer also should ensure that the effects of additives to the wasteform or barrier and the presence of chelating agents in the waste have been considered in the development of sorption coefficients and solubility limits.

- Ensure that changes in the chemical condition of the wasteform with time (see Section 4.3.3.1.2) are appropriately reflected in the release model (e.g., changes in K_d and solubility limits with pH and redox conditions).

- The reviewer should confirm that uncertainty in the K_d values is reflected in the release model. In general, literature-based values are more uncertain than site-specific values.

- Evaluate whether a solubility or partitioning release model is appropriate, and ensure that it is representative or conservative.

- Ensure that the release model is calibrated to release test data, scaling for surface area/volume, or that plans have been developed to acquire release rate data.

4.3.4 Radionuclide Transport

4.3.4.1 Areas of Review

This section focuses on evaluating transport of radionuclides beyond the engineered barriers. Transport of radionuclides to the receptor group(s) may be through air, water, or biotic pathways. The reviewer should consider the dimensions, locations, and spatial variability of the various transport pathways as well as temporal variations during the compliance period. The information reviewed for radionuclide transport should be consistent with the general information evaluated using Section 1 of this review plan.

4.3.4.1.1 Air Transport

The reviewer should evaluate the potential for airborne transport of radionuclides. Airborne transport evaluations should consider both suspension of radionuclide-bearing particulates and release of gaseous phase radionuclides (e.g., H-3, C-14, Kr-85). The reviewer should evaluate the significance of dilution and dispersion of the airborne radionuclides as they are transported in the atmosphere. Atmospheric transport of gaseous radionuclides will be affected by the height of the release above ground level, the speed and direction of the wind, atmospheric stability, and terrain. Radionuclide transport in the air will be affected by rainfall and particulate settling.

Information provided by DOE on airborne transport should be consistent with the site description (e.g., meteorology) (Section 1.1.3), information on inadvertent intrusion (e.g., farming or drilling) (Section 5), and climate (Section 4.3.1).

4.3.4.1.2 Surface Water Transport

The reviewer should evaluate information provided on the potential for radionuclides to be transported beyond the engineered barriers of disposal facility via surface water. In most cases, radionuclides will be transported from the waste disposal facility via other pathways before being transported in surface water pathways because it is unlikely surface water will directly intersect the waste disposal facility. Mechanisms for radionuclides to enter surface waters include but are not limited to deposition after airborne transport, groundwater discharge, and overland flow (e.g., associated with erosion). Information provided by DOE on surface water transport should be consistent with the information provided on climate and infiltration

(Section 4.3.1) and with the groundwater transport analyses for the site. The reviewer should evaluate information provided on potential dilution of radionuclide concentrations by mixing of disposal facility releases with surface waters. Typically, transport and residence times in surface water systems are relatively short; therefore, dispersion and dilution are the dominant processes that will mitigate the impact of contaminants released to most surface water bodies such as streams and rivers. In addition to transport in the water itself, the reviewer should consider the potential for radionuclide transport along with sediment suspended in the surface water.

The reviewer should evaluate the chemistry of the surface water and host rocks and sediments with respect to the potential for transport of radionuclides. The reviewer should evaluate the speciation of radionuclides in the surface water (e.g., sorption, precipitation, ion-exchange) if performance assessment modeling accounts for these processes. The reviewer should evaluate information provided on flooding at the site (e.g., flood hydrographs, probable maximum floods, maps of drainage basins, and maps of floodplains) (see Section 7).

4.3.4.1.3 Transport in the Unsaturated Zone

The reviewer should evaluate the information provided on the potential for radionuclides to be transported beyond the engineered barriers of the site along groundwater pathways through the unsaturated zone to the water table. Transport with groundwater is among the most likely processes for radionuclides to be transported from the engineered systems of the disposal facility. The reviewer should examine the hydrogeologic data for the site, including: the stratigraphy and geologic structures (e.g., fractures) that may affect groundwater flow, thicknesses of unsaturated strata, unsaturated hydraulic properties, depth to groundwater (including any perched zones that may affect transport), and recharge to and discharge from the site (including the potential effects of climate change). The reviewer should evaluate the information provided on the potential for diffusion and mechanical dispersion during transport. The reviewer should examine the significance of spatial variations in hydrogeologic properties, and examine the site design for information showing the positions of the engineered structures and anthropogenic features (e.g., infiltration caps) that may influence the unsaturated zone hydrology of the site. The reviewer also should evaluate the unsaturated zone flow and transport models used by DOE in its performance assessment, and how output is passed from the unsaturated zone flow and transport models to the saturated zone flow and transport models. The staff should review the lengths of the flow paths in the unsaturated zone, and evaluate the travel times estimated in the analysis. Information provided by DOE on groundwater transport should be consistent with the information provided for the site description (Section 1.1.3), climate and infiltration (Section 4.3.1), and for surface water transport (Section 4.3.4.1.2).

The reviewer should evaluate the chemistry of the groundwater and host rocks and sediments with respect to the potential for transport of radionuclides, including potential changes to the chemistry of the groundwater arising from interactions with the disposal system components and wasteform. The reviewer should evaluate the speciation of radionuclides in the groundwater (e.g., sorption, precipitation, ion-exchange, redox reactions), and the potential for colloid facilitated transport. The information provided by DOE should be consistent with the information provided for the radionuclide inventory (Section 3.1), engineered barriers (Section 4.3.2), source-term models (Section 4.3.3), and chemical environment (Section 4.3.3.1.4).

4.3.4.1.4 Transport in the Saturated Zone

The reviewer should evaluate the information provided on the potential for radionuclides to be transported from the disposal facility along groundwater pathways in the saturated zone to receptors. The reviewer should examine the hydrogeologic data for the site, including information provided describing the aquifers, aquitards, and geologic structures (e.g., fractures) that may affect groundwater flow in the saturated zone. The reviewer should examine the significance of spatial variations in hydrogeologic properties. The reviewer should evaluate DOE estimates of recharge to and discharge from the aquifers; groundwater flow velocities, gradients, and volumes; and ambient groundwater compositions. Water withdrawals and pumping of saturated zone aquifers may impact flow, especially dilution of radionuclide concentrations at the withdrawal point. The reviewer should evaluate information provided on the potential for diffusion, mechanical dispersion, decay and in-growth during transport. The reviewer should examine information provided on engineered structures (e.g., slurry walls) that might affect saturated zone flow and transport at the site. The reviewer should evaluate the saturated zone flow and transport models used by DOE in its performance assessment. The staff should review the lengths of the flow paths in the saturated zone, and evaluate the travel times estimated in the analysis. Information provided by DOE on saturated zone groundwater transport should be consistent with the information provided for the site description (Section 1.1.3), climate and infiltration (Section 4.3.1), surface water transport (Section 4.3.4.1.2), and groundwater transport in the unsaturated zone (Section 4.3.4.1.3).

The reviewer should evaluate the chemistry of the groundwater and host rocks and sediments, including potential changes to the chemistry of the groundwater arising from interactions with the disposal system components and wasteform. The reviewer should evaluate the speciation of radionuclides in the groundwater (e.g., sorption, precipitation, ion-exchange, redox reactions), and the potential for colloid facilitated transport. The information provided by DOE should be consistent with the information provided for the radionuclide inventory (Section 3.1), engineered barriers (Section 4.3.2), source-term models (Section 4.3.3), and chemical environment (Section 4.3.3.1.4).

4.3.4.2 Review Procedures

Review the transport modeling considering the information on the importance to disposal facility performance presented in Section 4.6. If DOE relies on the transport modeling to significantly reduce or mitigate radiological impacts, then the reviewer should perform a detailed review of the transport modeling. For example, if DOE relies on retardation during transport to provide significant delay in the transport of radionuclides, then the reviewer should perform a detailed review of the transport modeling. On the other hand, if DOE demonstrates the transport modeling to have a minor impact on the estimated radiological dose to the receptor, then the reviewer should conduct a simplified review. In a risk-informed, performance-based review, some of the review procedures may not be necessary for review of those models that have a minor impact on performance. The reviewer should perform the following procedures:

- Apply the general review procedures found in Section 4.2 to the modeling of radionuclide transport.

- Evaluate the potential for airborne transport of radionuclides. Verify that both suspension of radionuclide-bearing particulates and release of gaseous phase radionuclides are adequately considered. The reviewer should examine the potential significance of dilution and dispersion along the atmospheric transport path.

- Confirm that DOE has developed adequate technical basis for the dilution and dispersion of radionuclides by mixing in surface waters during transport. The reviewer should evaluate that adequate technical basis has been provided for incorporating the impact of variability, especially temporal, in surface water dilution.

- Determine that the development of models and data to represent the sorption and speciation of radionuclides during surface water transport considered the chemistry of the surface water and the mineralogy of sediments.

- Confirm that DOE has considered the potential for radionuclide transport along with sediment moved by the surface water, in addition to transport in the water itself. The reviewer should verify that the models are consistent with information provided on flooding potential at the site. For example, ensure that the potential for erosion and exhumation of wasteforms is considered for those areas where site characteristics (e.g., gullies, steep terrain) indicate that erosion is a significant process (see Section 7).

- Verify that the description of the hydrology, geology, climatology, geochemistry, design features, and physical and chemical phenomena that may affect radionuclide transport are adequate.

- Verify that conditions and assumptions in the modeling of radionuclide transport are readily identified, and are consistent with the body of data presented in the description.

- Verify that DOE has provided an adequate description of groundwater flow directions and velocities (horizontal and vertical) for each potentially affected aquifer. When applicable, the groundwater hydrology should be described by making use of hydrogeologic columns, cross-sections, and water table and/or potentiometric surface maps.

- Verify that the information on groundwater flow direction in each hydrological unit is consistent with the information presented about receptor location reviewed in Sections 1.1.3.1 and 4.1.1.4. The reviewer should ensure that the groundwater flow directions are consistent with placement of a member of the public at the point of highest exposure outside of the disposal area for demonstration of compliance with 10 CFR 61.41.

- Confirm that DOE has provided a sufficient description of numerical analysis techniques used to characterize the unsaturated and saturated zones, including the model type, justification, documentation, verification, calibration, and other associated information. In addition, verify that DOE has provided an adequate description that includes the input data, data generation or reduction techniques, and any modifications to these data.

- Evaluate the adequacy of the description of the speciation of radionuclides in groundwater (e.g., sorption, precipitation, ion-exchange, redox reactions), and the potential for colloid-facilitated transport.

- Ensure that transport properties (e.g., K_d values) used in the unsaturated and saturated zone transport models accurately reflect the mineralogy and water chemistry of the system.

- Evaluate the technical basis for the transport parameters and determine DOE modeling assumptions for radionuclide transport are appropriate. For example, confirm that the selected geochemical parameters (e.g., pH, redox, sorption coefficients) are representative of the expected chemical environment at the site.

- Confirm that DOE has used flow and transport parameters that are based on techniques that may include laboratory experiments, field measurements, information from comparable sites, and process-level modeling studies, conducted under relevant conditions. Confirm that site-specific information was used, when available, in the development of transport parameters and models.

- Ensure that adequate descriptions are provided of how flow and transport data were used, interpreted, and incorporated into the performance assessment parameters.

- Ensure that DOE provided hydrologic properties (e.g., moisture characteristic curve parameters) for modeling unsaturated zone flow that are supported by empirical measurement. If generic information is used, the reviewer should ensure that it is sufficiently conservative. The reviewer should verify that the information is consistent with related hydrogeologic data for the site, including observed spatial variability in the hydrologic properties.

- Verify that parameter values for processes such as matrix diffusion, dispersion, and groundwater mixing are based on reasonable assumptions about climate, aquifer properties, and groundwater volumetric fluxes;

- Confirm that the uncertainties in transport properties (e.g., K_d values) are reflected in the unsaturated and saturated zone transport models. In general, literature-based values are more uncertain than site-specific values.

- Ensure that limitations and uncertainties of the K_d model have been adequately considered if a K_d model is used to represent radionuclide transport and if the transport submodel has been identified as having a significant effect on dose results (e.g., by significantly delaying radionuclide arrival and resulting in significant decay). The reviewer may consider "Understanding Variation in Partition Coefficient, K_d, Values" (EPA, 1999).

- Examine the results of any DOE field transport tests or observations of leaks and spills and verify that the performance assessment model results are consistent with the field experiments or observations, or confirm that an adequate technical basis has been provided to explain any differences. For example, the performance assessment transport models should provide results that are consistent with the transport of existing contaminant plumes as observed through environmental monitoring.

- Ensure that the output from the unsaturated zone flow and transport model is consistent with the input into the saturated zone flow and transport model.

- Ensure, if the water table is shallow and the unsaturated zone flow paths are short (less than 5 m), that DOE has evaluated the impact of water table fluctuation and provided adequate technical basis that fast pathways are not present that would significantly impact the travel time through the unsaturated zone.

- Ensure that adequate technical basis is provided for the representation of the in-growth of daughter radionuclides in the modeling of radionuclide transport. Many computer codes assign the same transport properties to the daughter radionuclides that in-grow from parents during transport. If significant in-growth can occur, the transport of daughters that are more mobile than their parent radionuclide may be significantly underestimated.

- Verify for those radionuclides for which transport in groundwater is important to estimating the dose to receptors, that adequate model support has been provided for the transport modeling such as comparison to laboratory experiments, field measurements, observations of leaks and spills, process-level modeling studies conducted under relevant conditions, natural analogs, and independent peer review. For observational types of information such as monitoring of leaks and spills, the reviewer should confirm that there is adequate similarity of the conditions of the leak or spill to the modeled conditions (e.g., mineralogy, pore water chemistry, hydraulic properties).

- Ensure the modeling of saturated transport is consistent with site-specific information about the hydrological units (e.g., information reviewed according to Section 1.1.3.5). The reviewer should ensure that the modeling of any units identified as aquitards is consistent with information about the spatial variability of the unit and the presence of any fast pathways through the unit (e.g., areas where the unit pinches out or becomes thin and high-permeability features).

- To the extent practical, consider other relevant sources of information, such as characterization and modeling performed for existing contamination or other waste disposal facilities at the DOE site, that may support or refute the hydrogeologic conceptual model, analysis, and modeling provided by DOE for the waste determination.

- Eensure that alternative modeling approaches, if applied, are consistent with available data and current scientific knowledge.

- Confirm that outputs of radionuclide transport models used in the performance assessment reasonably agree with or bound the results of corresponding process-level models, empirical observations, or both.

- Verify that procedures to construct and test the mathematical and numerical models of radionuclide transport are well-documented and that the procedures are based on modeling approaches that have been accepted by the scientific community.

4.3.5 Biosphere Characteristics and Dose Assessment

For the purpose of this review, the biosphere is the physical environment accessed by the receptor in the dose assessment. The dose assessment is that portion of the performance assessment model that calculates dose to the receptor from radionuclides transported from the disposal site to the biosphere. The dose assessment includes all the applicable local fate and transport pathways within the biosphere that culminate in exposure to the receptor (e.g., irrigation of soils with contaminated groundwater, plant and animal uptake, consumption of local food products). Because offsite receptor locations can have different characteristics from the disposal site, and some specialized information may be needed to support the dose assessment, the characteristics of the biosphere must be reviewed to verify that the inputs and assumptions have adequate technical basis.

4.3.5.1 Areas of Review

Dose assessment input parameters may be generally classified as behavioral, metabolic, or physical. Behavioral parameters collectively describe the behavior hypothesized for the potentially exposed individual that is normally consistent with local practices (e.g., time spent gardening, vegetable consumption rates). Metabolic parameters also describe the exposed individual, but generally address involuntary physiological characteristics of the individual (e.g., breathing rates, factors converting intake of unit activity to dose [by radionuclide]). Physical parameters collectively describe the physical characteristics of the site (e.g., geologic, hydrologic, geochemical, ecological, and meteorologic inputs). This section is focused on the review of the physical, behavioral and metabolic input parameters used in the dose assessment modeling for the performance assessment.

4.3.5.1.1 Exposure Pathways and Dose Modeling

The reviewer should evaluate information provided to ensure that transport modeling via groundwater, surface water, and air pathways are properly integrated with dose assessment models. For example, groundwater may be used as a source for drinking water (both human and livestock), irrigation of crops, and as a primary source for meeting various domestic, commercial, and industrial needs. Therefore, scenarios involving radionuclides transported in groundwater may involve dose modeling that includes direct human ingestion of contaminated water, and transfer of contaminants to crops and livestock. Furthermore, buildup of contaminants in soils can result in inhalation of radionuclides either as particulates suspended in air or as gases emanated from the soils. Direct exposure to contaminated soils is also a potentially applicable dose pathway. Surface water transport can lead to similar exposure pathways if used as a primary source of water for municipal needs. Direct exposures can occur from contaminated surface water during recreational activities such as bathing or swimming. Air transport of gaseous or particulate releases can result in direct inhalation dose from breathing the air, or can result in applicable soil related pathway exposures from deposition of particulates to the ground surface. The reviewer should ensure the selected exposure pathways are reasonably complete (e.g., they represent the primary means by which humans can be exposed to radionuclides released to air, groundwater, and surface water) and are consistent with regional practices in the vicinity of the disposal site.

Justification should be provided for excluding applicable exposure pathways or implementing unique or novel approaches to modeling.

4.3.5.1.2 Site-Specific Input Parameter Values

The reviewer should evaluate site-specific and generic information provided for the biosphere characteristics and dose assessment. Making a decision as to whether site-specific or generic information for biosphere model input parameters should be used would generally consider the characteristics of the scenario and receptor groups considered, the modeled system, what the parameter represents, and how the parameter is used in the code. Based on those considerations, a value for the input parameter is developed that is appropriate for both the system being modeled and for the conceptual and numerical models implemented by the code.

Because there is always uncertainty associated with the behavior of a hypothetical receptor, it is often necessary to rely on a generically defined receptors for behavioral and metabolic input parameters. Behavioral and metabolic characteristics of receptors must be representative of average members of the receptor group assumed in the modeled exposure scenario. Some performance assessment codes may use default model values for the behavioral and metabolic parameters. The reviewer should ensure that the use of such default parameters is consistent with characteristics described for the average member of the receptor group (e.g., if the average member of the critical group is an adult, then it would be inappropriate to use default soil ingestion rates that are appropriate for a child). Commonly, the average member of the critical group is defined as an adult because adults are exposed to more pathways. However, in certain scenarios with limited pathways, children may be the critical group.

4.3.5.2 Review Procedures

The following review procedures are focused on evaluation of the behavioral and metabolic input parameters used in dose assessments for demonstrating protection of the general population from releases of radioactivity. These review procedures are also applicable to behavioral and metabolic input parameters used in dose assessments for inadvertent intruder scenarios and scenarios to demonstrate protection during operations. The reviewer should perform the following procedures:

- Examine the coupling of groundwater, surface water, and air transport models to biosphere models. The transport model outputs (e.g., fluxes or concentrations at the biosphere interface) should be linked or have information transferred to the applicable pathways in the biosphere dose assessment model(s).

- Verify that conceptual models for the biosphere include consistent and defensible assumptions based on regional practices and characteristics (i.e., conditions known to exist or expected to exist at the site or surrounding region).

- Confirm that dose assessment results are stratified by exposure pathway (e.g., drinking water, crops, meat, milk, fish, inhalation, external) to assess the reasonableness of pathway contributions to the total dose.

- Verify input parameters and technical bases for the parameters (e.g., transfer factors, consumption rates) for any pathways that are key contributors to dose or have an unexpectedly high or low contribution to the calculated dose.

- Verify that the internal and external dosimetry approach is consistent with dosimetry methods accepted by NRC (e.g., ICRP 26, ICRP 72) (see Section 4.6.1.3).

- Ensure that selection of the appropriate lung clearance class for inhalation dose coefficients, and the fractional uptake to blood for ingestion dose coefficients have an adequate technical basis (e.g., based on the chemical form of the material inhaled or ingested material) or that the highest (most conservative) values of available coefficients are used.

4.4 Computational Models and Computer Codes

4.4.1 Areas of Review

This section focuses on ensuring that codes used to develop a performance assessment model are appropriately chosen, have undergone quality assurance testing (see Section 8), and that model scenarios and conceptual models reviewed in Section 4.1 of this review plan have been appropriately incorporated into the computational model. The reviewer will benefit from being familiar with NUREG–1757 (NRC, 2003a, Vol. 2, Appendix I), which provides guidance for selecting computer codes and incorporating conceptual models into computational models.

The reviewer should evaluate information provided to ensure that acceptable quality assurance testing of codes has been conducted (see Section 8). The reviewer is expected to conduct a more detailed and thorough review of less common codes and codes that may have been developed for site-specific application. For example, to complete a review of a well-established commercial product it may only be necessary to review input files (e.g., for errors such as unit conversion problems) and output files, and to ensure the model has been applied for a range of conditions for which the software has been validated. On the other hand, a code developed by DOE or its contractors for a site-specific evaluation may require a more thorough examination of the quality assurance documentation to ensure an appropriate and accurate implementation of the conceptual model.

The process of developing a performance assessment model typically has many steps. A number of these steps are reflected in associated review procedures in this section instead of in Section 8 because the analysis steps for the performance assessment may not be explicitly represented in quality assurance procedures (e.g., for data or software) but can be important to performance assessment analysis.

4.4.1.1 Modeling Approach: Probabilistic or Deterministic

DOE may select either a deterministic approach or a probabilistic approach for the analysis to demonstrate compliance with the performance objectives in 10 CFR Part 61, Subpart C. A deterministic analysis uses single parameter values for every variable in the code. By contrast, a probabilistic approach assigns parameter ranges to certain variables, and the code samples and selects the values for each variable from the parameter probability distribution each time the dose is calculated. While a deterministic analysis calculates the results from a single solution of the equations each time the user runs the code, a probabilistic analysis calculates hundreds of solutions to the equations using different values for the parameters from the parameter ranges. The deterministic model, without additional sensitivity analyses, gives no indication of the sensitivity of the results to certain parameters or of the importance of the uncertainty in the parameters. Therefore, applying a deterministic approach may result in the need for stronger justification of code input parameter values and may require further analysis of doses using upper or lower bounding conditions to gain insights on the range of dose estimates.

A preferred method is to use a risk-informed approach to performance assessment in which probabilistic sampling is used for model parameters with irreducible uncertainty that cannot otherwise be shown to be unimportant to system performance. In this type of model, parameters that are well constrained or that can logically be shown to be of little significance are assigned deterministic values, while the remaining parameters are assigned probability distributions that cover the expected ranges of the parameters. Probabilistic approaches to performance assessment are preferred because they readily permit propagating and assessing the impact of uncertainty on the model results.

Although probabilistic approaches are preferred, DOE is not precluded from using a deterministic model to demonstrate compliance with performance objectives. In general, if deterministic modeling is used, it should be reasonably conservative and sufficiently documented so that a subject matter expert, with minimal interaction with those who performed the assessment, could come to a conclusion that the analysis was conservative. Additional sensitivity analyses to identify significant parameters, model components, and processes may be needed if only deterministic analyses are performed.

4.4.1.2 Model Development

Sections 4.1-4.3 of this review plan contain guidance to ensure that the models used in the DOE performance assessment (e.g., source term, water infiltration, engineered barrier capability, radionuclide transport, receptor dose) and dose calculations are properly integrated with the overall system model. The reviewer should ensure that the performance assessment models are developed with proper integration of models for each of the exposure scenarios (e.g., onsite, offsite, and inadvertent intruder scenarios). If a probabilistic model is used, the reviewer should ensure that the number of model realizations used to estimate expected dose to a receptor is sufficient to achieve a stable mean dose estimate (i.e., results do not change significantly if more model realizations are simulated). Additionally, the reviewer should ensure that the numerical accuracy of model calculations have been verified as part of the code development process.

4.4.2 Review Procedures

- The reviewer should determine the adequacy and completeness of the quality assurance documentation of the code/model (see Section 8). This review should include documentation pertaining to: (1) software requirements and intended use, (2) software design and development, (3) software design verification, (4) software installation and testing, (5) configuration control, (6) software problems and resolution, and (7) software validation.

- The reviewer should ensure that the computational model is compatible with the disposal site conceptual model, including the pathways and the exposure scenario. The source-term assumptions of the selected code should also be compatible with site-specific source term. For example, if the code selected for source-term analysis in the performance assessment does not estimate diffusive releases, the reviewer should ensure that diffusive releases are not important to the performance of the disposal facility.

- The reviewer should evaluate information on the limitations of the selected codes to ensure that modeling results and modeling approaches are not being arbitrarily constrained by the limitations of the codes selected for the analysis. For example, the selected code may not be able to model the effects of preferential pathways, model certain exposure pathways, or represent changes in model parameters as a function of time (e.g., for barrier degradation).

- The reviewer should evaluate the code documentation to verify that the exposure scenarios of the performance assessment code are compatible with the intended scenarios for the site.

- The reviewer should verify that unit conversion errors have not occurred as a result of the passage of information between models in the analysis.

- The reviewers should ensure that contaminant fluxes have not been arbitrarily dispersed (e.g., numerically) or diluted to a significant degree in the performance assessment modeling (e.g., artificial dilution of fluxes into larger than expected depths of the saturated zone because of the size of finite elements in the groundwater model). A minor amount of numerical dispersion may be expected.

- If a probabilistic analysis is performed, the reviewer should ensure that an adequate number of stochastic realizations have been executed to produce stable output.

- If a deterministic analysis is performed, the reviewer should determine if the overall performance assessment is sufficiently conservative to account for uncertainty in the parameters and models. For example, the reviewer can make a qualitative, semi-quantitative, or quantitative comparison of a list of conservative assumptions or approaches in the analysis with a list of key parameters that were represented as deterministic in the analysis but would be expected to be uncertain.

- The reviewer should ensure that the performance assessment model results are not sensitive to time-stepping or spatial discretization of the model domain.

- The reviewer should ensure the performance assessment codes properly account for radionuclide decay and ingrowth. The codes should provide a mechanism to track the amounts of radioactivity throughout the disposal system and site over the performance period, including which environmental media the radionuclides are present in or associated with.

- The reviewer should ensure that the treatment of the transport properties assumed for daughter radionuclides created during a transport leg do not underestimate dose. For example, many dose modeling codes do not assign new properties to daughter radionuclides that are created during transport, and can overestimate transport times for daughters that are more mobile than the parent (e.g., Np-237 ingrowth from Am-241).

4.5 Uncertainty/Sensitivity Analysis for Overall Performance Assessment

4.5.1 Areas of Review

General approaches to handling data and model uncertainty are described in Section 4.4.1.1. As discussed previously, probabilistic approaches to performance assessment are preferred because they readily permit propagating and assessing the impact of uncertainty on the model results. DOE is not precluded, however, from using a deterministic model to demonstrate compliance with performance objectives. In general, if deterministic modeling is used, it should be reasonably conservative so that a subject matter expert with minimal interaction with those who performed the assessment could conclude that the analysis was conservative.

For modeled processes and input parameters that are highly uncertain and cannot clearly be established as conservative, sensitivity analyses are necessary to establish the relative importance of these processes and parameters to the performance assessment dose calculations. A summary of different methods for sensitivity and uncertainty analyses can be found in NUREG–1757 (NRC, 2003a, Vol. 2, Appendix I, Section I.7) and in NUREG-1573 (NRC, 2000, Section 3.3.2).

As discussed previously, different approaches to performance assessment calculations (e.g., deterministic, probabilistic) have their advantages and disadvantages with regard to uncertainty and sensitivity analysis. While deterministic analysis can be a suitable methodology for performance assessment, it can also present a challenge for a dynamic system that responds nonlinearly to the independent variables. When there are numerous inputs (e.g., data or models) that are uncertain, the evaluation of the impacts of the uncertainties on the decision can be difficult. Typical one-off type of sensitivity analysis where a single parameter is increased or decreased will only identify local sensitivity within the parameter space, such that it may not clearly identify the risk implications. A deterministic approach can be useful to bound uncertainty when the analysis can be demonstrated to be conservative using bounding assumptions. A probabilistic approach can have distinct advantages when there are a number of uncertainties that may significantly influence the results of a performance assessment. For example, the uncertainty introduced by changing effectiveness of a chemical barrier over time can be represented by selecting appropriate ranges in the transport parameters for the barrier.

If DOE has performed a deterministic performance assessment, then the reviewer should examine the sensitivity analyses provided by DOE. Review the basis for selecting the parameters and combinations of parameters used in the sensitivity analysis. The ranges in the parameters selected should be consistent with the variability and uncertainty in the parameters, and provide reasonable assurance that the effects of the uncertainty on performance are bounded. The reviewer should examine the technical basis used to support the variability and uncertainty. Appropriate combinations of parameters should be used to capture the interdependence of key parameters, and ensure consistency through the overall performance assessment.

Because conceptual models are developed based on limited data, in most cases more than one possible interpretation of the site can be justified based on the existing data. This uncertainty should be addressed by developing multiple alternative conceptual models and proceeding forward with the conceptual model that provides the most conservative estimate of the dose and yet is consistent with the available data. Alternatively, DOE could provide analyses for multiple conceptual models to develop a range of dose estimates. Consideration of unrealistic and highly speculative conceptual models should be avoided. Consistent with the overall dose modeling framework of starting with simple analyses and progressing to more complex modeling, as warranted, it may be advisable for the analyst to begin with a simple, conservative analysis that incorporates the key site features and processes and progress to more complexity only as merited by site data. It is important to stress that a simple representation of the site, in itself, does not mean that the analysis is conservative. The reviewer should evaluate whether DOE has presented information demonstrating that its simplification is justified, based on what is known about the site and the likelihood that alternative representations of the site would not lead to higher calculated doses.

4.5.2 Review Procedures

- If a deterministic model framework is adopted, ensure that key model parameters are either conservative, well-justified, or that sensitivity analyses have been provided to demonstrate the overall risk significance of uncertain parameters.

- The reviewer should evaluate the ranges of parameters used in sensitivity analysis and verify that they reasonably cover the expected ranges.

- The reviewer should ensure that appropriate combinations of parameters have been used in sensitivity analysis to capture the interdependence of key parameters. For example, the reviewer should consider (1) combinations of factors affecting radionuclide release that may be physically coupled, such as increased infiltration that may result in more rapid engineered barrier and wasteform deterioration and increased release rates from the wasteform, (2) combinations of factors that would be expected to occur together, such as cracking of a wasteform due to seismic activity that may impact both physical and chemical durability of the wasteform; and (3) combinations of factors affecting transport such as decreased K_d values for chemically similar radionuclides due to an external factor (e.g., leaching of alkalinity from a disposal facility).

- If DOE has adopted a probabilistic framework, evaluate whether it is sufficient to support understanding of the overall risk significance of uncertain model input parameters.

- If DOE has adopted probabilistic analyses, the reviewer should ensure that unrealistic ranges in parameter distributions are not used that could result in “risk dilution.” This is especially important when the parameter distribution is assigned based on generic or literature information, and when the parameter influences the timing of the occurrence of the peak dose (e.g., K_d distributions).

- As appropriate, ensure that DOE has considered alternative conceptual models and that demonstrations of compliance with performance objectives are based on well-supported conceptual models or the most conservative model that is consistent with site characteristics.

4.6 Evaluation of Model Results

4.6.1 Areas of Review

4.6.1.1 Defining Barrier Contributions

Although the prior sections of this review plan address the review of detailed descriptions of engineered and natural barriers and their implementation in the performance assessment model, it is important that the reviewer ensures the DOE discussion of performance assessment results includes a quantitative and qualitative analysis and description of how engineered and natural barriers are functioning in the performance assessment model to limit or prevent doses. Information defining barrier contributions should be used by the reviewers to risk-inform their review.

The term "barrier" as used in this context, applies to engineered or natural components of the system that may reduce or mitigate risks. Engineered components may be those components specifically designed for the waste disposal facility (e.g., an infiltration cap), or in the case of closure of a waste storage facility, those components of the waste storage facility not specifically designed for long-term performance but that may impact the long-term performance of the system (e.g., a vault holding an underground tank). Results may be provided for intact versus failed (or realistically degraded) barrier performance for individual barriers (and collections of barriers) to gain insights into the importance of barriers on the performance assessment results. In addition, results may be presented with only the natural system or only the engineered system present in the analysis to show the relative contribution of the engineered and natural systems to overall performance of the waste disposal facility. Without an analysis of barrier contributions, the influences of barriers on performance assessment results may not be transparently described or self-evident. In this regard, staff should verify the contributions of key engineered and natural barriers to the performance assessment results are adequately described by DOE. The reviewer should ensure that information for the barrier functions, including the magnitude of the impact of the barrier function on estimated doses, are reasonable and consistent with the descriptions of the engineered barriers (see Section 4.3.2) and characteristics of the disposal site.

4.6.1.2 Evaluating Intermediate Model Results

The main purpose of the performance assessment model is to estimate long-term radiological dose to receptors. Typically a large amount of intermediate outputs is produced during execution of a performance assessment model, such as infiltration through a cap or the fractional release rate from a wasteform. In addition to evaluating information on the contribution of engineered barriers to reduce or mitigate radiological dose, the reviewer should evaluate intermediate outputs of performance assessment models to understand the interactions of barriers and any possible masking effects of barriers. For example, the infiltration rate through an engineered cap may not be a risk-significant element of the analysis if the hydraulic properties of the wasteform limits flow to lower values than what the engineered cap can provide. However, in this case the engineered cap may be providing a redundant performance function and it may also be contributing to mitigating degradation mechanisms of the wasteform associated with water flow (e.g., leaching). As appropriate, the reviewer should examine the intermediate results of the performance assessment calculations to understand the integration of the performance assessment models.

4.6.1.3 Final Dose Calculations

Numerous NRC guidance documents provide recommendations on the approach and use of the specific dose conversion factors used in performance assessments. These include NUREG–1573 (NRC, 2000), which provides guidance on the use of pathway dose conversion factors for calculating doses via potential exposure pathways, and NUREG–1757 (NRC, 2003, Vol. 2, Appendix I), which provides guidance on the use of specific dose conversion factors such as those developed by EPA and published in Federal Guidance Report Nos. 11 and 12 (EPA, 1988, 1993).

The reviewer should assess the dose conversion factors for inhalation and ingestion, to ensure that the factors used are those developed by Environmental Protection Agency, published in Federal Guidance Report No. 11 (EPA, 1988). Similarly, the reviewer should ensure that the EPA external dose factors published in Federal Guidance Report No. 12 (EPA, 1993) were used. These dose factors were selected to ensure consistency of the dosimetry models used in deriving these factors with NRC regulations in 10 CFR Part 20. The reviewers should evaluate information on the dose conversion factors or correction factors used by DOE in the analysis of external doses to ensure appropriateness for the thickness, shielding, and extent of contamination.

DOE may request to use the latest dose conversion factors (e.g., International Commission on Radiological Protection 72). However, DOE should not "pick and choose" dosimetry methods for individual radionuclides.

4.6.1.4 Comparison to Performance Objectives

The postclosure performance assessment is used to demonstrate compliance with 10 CFR 61.41, "Protection of the general population from releases of radioactivity," which states:

> "Concentrations of radioactive material which may be released to the general environment in groundwater, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable."

The 0.25 mSv/yr (25 mrem/yr) limit applies for the post-closure period of a disposal facility. NRC expects DOE to express this limit in terms of total effective dose equivalent (NRC, 2005, 1999, Footnote 1). For probabilistic performance assessment models, it is acceptable to use the peak of the mean dose history to demonstrate compliance with this performance objective.

The reviewer should evaluate that the appropriate dose limits are applied. For example, to evaluate whether the performance objectives in 10 CFR 61.41 can be met, probability can be considered in the consequence analysis, and the annual dose limit to the member of the general public is 0.25 mSv (25 mrem) (NRC, 2005, 1999, Footnote 1). For example, disposal facility performance may be severely impacted by a low-frequency, large-magnitude seismic event. In this case, it would be appropriate to factor in the event probability when estimating the risk to the public. In estimating dose to an inadvertent intruder (see Section 5), however, the probability of the intrusion in the stylized analysis is assumed to be 1, and a higher annual dose limit of 5 mSv (500 mrem) is assumed for an inadvertent intruder (NRC, 1981).

The limit provided in 10 CFR 61.41 (0.25 mSv/yr [25 mrem/yr]) applies to the cumulative impacts from the LLW disposal units that could contribute to the receptor dose (e.g., tanks in a tank farm subject to past, present, and future waste determinations). Because the amount of waste associated with future determinations will not be known in the present, the reviewer will need to consider estimated doses in previous waste determinations for different sources (i.e., those not part of the current waste determination) that could contribute to receptor doses. Eventually, demonstration of compliance with 10 CFR 61.41 will be based on the maximum dose to a receptor from all disposal units subject to waste determinations. All disposal units may not contribute to receptor doses at a particular location (e.g., groundwater flow paths may be in different directions due to the presence of a groundwater divide). The reviewer should note in the TER the cumulative impact from past and current waste determinations.

Demonstration of stability of the disposal site after closure requires a separate technical evaluation and review procedures for this performance objective are described in Section 7 of this review plan. Reviewers of the postclosure performance assessment models should evaluate whether the site stability performance objective is met because long-term site stability is typically an important assumption in the performance assessment conceptual model.

4.6.2 Review Procedures

The following review procedures are focused on ensuring that performance assessment model results are sufficient for comparison to performance objectives. The reviewer should perform the following review procedures:

- Examine the descriptions of the methodology used for dose conversion of internal and external exposure to releases of radioactive material.

- Ensure the dose conversion factors or correction factors used by DOE in the analysis of external doses are appropriate for the thickness, shielding, and extent of contamination.

- Review the DOE description of the comparison of performance assessment model output to the applicable performance objectives in 10 CFR Part 61, Subpart C. Ensure that the description includes an appropriate performance measure such as peak of the mean dose for probabilistic assessments or peak dose for deterministic assessments.

- Ensure that descriptions of performance assessment results are sufficient to permit comparison of model results to the performance objective of 10 CFR 61.41.

- Ensure that DOE is using the appropriate dose limit from 10 CFR 61.41 for the public during the period after active institutional controls.

- Ensure that probabilities have been appropriately applied to the determination of whether the performance objective in 10 CFR 61.41 can be met, if necessary.

- Evaluate compliance with 10 CFR 61.41 by ensuring that the maximum cumulative dose to a public receptor from unique disposal units evaluated in past waste determinations and the present waste determination does not exceed 0.25 mSv/yr (25 mrem/yr). The reviewer should assess that the location of the receptor that is expected to receive the maximum cumulative dose was appropriately determined or bound (e.g., impacts from unique disposal units were assumed to be along the same groundwater flowpath).

- Evaluate the sensitivity/uncertainty analyses provided with the performance assessment to determine whether the analyses are sufficient to permit evaluation of model sensitivity to uncertain processes and input parameters.

- Verify that modeled processes and input parameters are treated in a manner that is either demonstrably conservative, sufficiently constrained by site data, or otherwise demonstrated to have insignificant effect on modeled dose estimates if a conservative deterministic model is used in lieu of sensitivity analyses to address parameter uncertainty.

- Ensure that DOE has addressed uncertainty in the timing of the peak dose if a deterministic analysis is used. The reviewer should evaluate whether significant peak doses occur after the period of performance, and if uncertainties in any of the transport or release models or parameters would be sufficient to move the peak doses into the performance period.

- Ensure that DOE has provided an adequate technical basis to explain differences between current and past modeling of the disposal facility, as appropriate.

- Verify that DOE has provided a complete description of all the key barriers included in the performance assessment model. This review should be integrated with the detailed technical reviews conducted in Sections 2–8.

- Verify that the DOE description and analysis of performance assessment results provides a complete (qualitative and quantitative) analysis and description of barrier contributions to performance assessment results. The discussion of results should include a transparent description of how the modeled disposal site system is functioning with an emphasis on barriers to release and transport that affect the magnitude or timing of estimated doses. A brief example of the type of information that may be included in such a barrier performance analysis description is provided in the following paragraph:

  – The engineered cap reduces infiltration to the waste from 25 cm/yr to 1 cm/yr for 1000 years. Without the engineered cap present, the dose only increased a factor of 2 from the nominal case because of the low hydraulic properties of the wasteform. In the case of the cap being failed and the wasteform degrading hydraulically, the dose is increased by a factor of 20 from the nominal case. The chemical properties of the wasteform provide a significant barrier to radionuclide release, even if the system does not perform as intended from a hydrologic standpoint. Without the chemical properties of the wasteform, the dose would increase an additional factor of 100, primarily as a result of the release of relatively strongly sorbing Np-237 and Pu-239.

- Following review of the DOE description of performance assessment results, the reviewer should ensure an adequate technical basis is provided for barrier capabilities that contribute significantly to performance assessment results (i.e., in particular, those barriers that significantly reduce estimated doses or significantly delay the estimated doses). The characteristics of the barriers should be described in detail to provide confidence in the performance capabilities of the barriers.

- Evaluate whether the DOE performance assessment has appropriately considered applicable barrier interactions (e.g., change or variation in chemistry that degrades an engineered barrier could also influence sorption or source term release estimates). Analysis of the performance of individual barriers one at a time may be incomplete, because it can miss plausible and potentially important interactions of features and processes that can amplify impacts on system performance.

- Evaluate whether the modeling of barriers in the performance assessment appropriately considers and propagates applicable uncertainties and variabilities or (in particular for deterministic analyses) that barriers are represented conservatively.

- Verify that the description of each barrier is consistent with the detailed description and supporting information for barrier features and capabilities.

- Evaluate intermediate results from the DOE performance assessment to understand the interactions of barriers and any possible masking effects of barriers.

4.7 ALARA Analysis

The focus of this part of the review is on assessing compliance with the requirement in 10 CFR 61.41 that releases of radioactivity in effluents from the disposal facility to the general environment be maintained as low as is reasonably achievable (ALARA). The review of the postclosure performance assessment to determine compliance with the dose requirements of 10 CFR 61.41 is described in Sections 4.1–4.6. Review of the performance objective for maintaining radiation exposures to individuals during operations ALARA, as required in 10 CFR 61.43, is discussed in Section 6 of this review plan.

4.7.1 Areas of Review

In general, the conclusion that proposed waste management activities will result in the removal of highly radioactive radionuclides to the maximum extent practical (see Section 3) supports the conclusion that releases of radioactivity in effluents from the disposal site will be maintained ALARA. Thus, a reviewer should begin the evaluation of compliance with the ALARA requirement of 10 CFR 61.41 by completing the review described in Section 3 of this review plan. In addition, because steps taken to stabilize waste also are expected to limit radionuclide release from the disposal facility, stabilization activities also are relevant to the assessment of compliance with the requirement to maintain effluents ALARA. Therefore, a reviewer also should evaluate DOE's description of actions taken to stabilize the waste to minimize the release of radionuclides from the disposal facility (e.g., efforts to optimize solidification of liquid wastes, or efforts to optimize mixing or encapsulation of residual tank waste with grout). The review should be focused on the dominant pathways of radionuclide release from the disposal facility and the factors causing the most uncertainty in release rates, as determined in DOE's performance assessment and independent analyses.

4.7.2 Review Procedures

After completing the review described in Section 3 of this review plan, the reviewer should identify the dominant pathways of radionuclide release from the disposal site based on the results of DOE's performance assessment and any independent analysis used in the review described in Sections 4.1-4.6 of this review plan. In the identification of dominant release pathways, the reviewer should also identify key uncertainties that may impact which factors dominate radionuclide release (e.g., placement of waste in areas thought to be especially prone to the development of preferential pathways for infiltrating water may cause significant uncertainty in releases to groundwater). In general, the reviewer should determine what steps have been taken to limit the release of radionuclides through the dominant release pathways and to limit the potential for high release rates due to alternate release mechanisms. Specifically, the reviewer should perform the following:

- Confirm that DOE has provided sufficient support through its performance assessment that it can meet the dose requirements of 10 CFR 61.41 (see Sections 4.1-4.6);

- Determine whether waste is placed in areas that are susceptible to the formation of preferential pathways for infiltrating water (e.g., along joints between dissimilar materials) and whether appropriate steps have been taken to move waste from those areas, if practical.

- Determine whether appropriate efforts have been made to optimize the solidification of any relevant liquid waste (in general, wastes containing more than 1% residual liquid by volume are not suitable for near-surface disposal [10 CFR 61.56]).

- If stabilizing material is added to a waste, determine whether appropriate efforts have been made to optimize mixing or encapsulation of the waste with the stabilizing material (e.g., evaluate the selection of methods used to optimize mixing of residual waste and grout in tanks).

The determination of whether efforts to optimize waste stabilization are appropriate should be evaluated based on quantitative measures to the extent possible, using procedures similar to those discussed in Section 3. For example, if releases from wastes located along the edges of a tank contribute significantly to releases of radionuclides into groundwater, or contribute significant uncertainty to the expected releases from the site, the reviewer should evaluate DOE's selection of options available to move or stabilize the wastes present along the edge of the tanks using procedures similar to those used to evaluate DOE's selection of technologies available to remove the waste from the tank, as described in Section 3. Similarly, to determine whether procedures that could be used to stabilize waste are practical, it may be necessary to compare the costs and benefits of additional stabilization, as described in Section 3.4.

4.8 References

Bradbury, M., and F.A. Sarott. “Sorption Databases for the Cementitious Near-Field of a L/ILW Repository for Performance Assessment.” PSI Bericht 95-06, Wurenlingen and Villigen, Switzerland: Paul Scherrer Institut. 1995

U.S. Environmental Protection Agency (EPA). “Federal Guidance Report No. 12: External Exposure to Radionuclides in Air, Water and Soil.” EPA–402–R–93–081. September 1993.

———. “Federal Guidance Report No. 11: Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion.” EPA–520/1–88–020. September 1988.

———. “Understanding Variation in Partition Coefficient, K_d, Values.” EPA-402-R-99-004A. August 1999

U.S. Nuclear Regulatory Commission (NRC). “Draft Environmental Impact Statement on 10 CFR Part 61 Licensing Requirements for Land Disposal of Radioactive Waste.” NUREG-0782. September 1981.

———. “Final Environmental Impact Statement on 10 CFR Part 61 Licensing Requirements for Land Disposal of Radioactive Waste.” NUREG-0945. 1982.

———. “Generic Technical Position on Peer-Review for High-Level Nuclear Waste Repositories.” NUREG-1297. February 1988a.

———. “Generic Technical Position on Qualification of Existing Data for High-Level Nuclear Waste Repositories.” NUREG-1298. February 1988b.

———. “Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program.” NUREG-1563. November 1996.

———. “Disposal of High-Level Radioactive Wastes in a Proposed Geological Repository at Yucca Mountain, Nevada.” Proposed Rule. *Federal Register.* 64 FR 8640. February 1999.

———. “A Performance Assessment Method For Low-level Waste Disposal Facilities: Recommendations of NRC’s Performance Assessment Working Group.” NUREG-1573. October 2000.

———. “Consolidated NMSS Decommissioning Guidance.” Vols. 1–3. NUREG-1757. September 2003.

———. “Technical Evaluation Report for the U.S. Department of Energy, Savannah River Site Draft Section 3116 Waste Determination for Salt Waste Disposal.” Letter from L. Camper to C. Anderson, DOE. December 2005.

5 INADVERTENT INTRUSION

The performance objective for protection of the inadvertent intruder is provided in 10 CFR 61.42. Specifically, the staff review should confirm whether design, operation, and closure of the land disposal facility will ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls for the disposal site are removed. The performance objective in 10 CFR 61.42 does not provide a numerical dose criteria for protection from the inadvertent intruder. In previous waste determination reviews (NRC, 2000a, 2003a, 2005), the U.S. Nuclear Regulatory Commission (NRC) has applied the whole body-dose equivalent limit of 5 mSv/yr (500 mrem/yr) described in Section 4.5 of Volume 2 from the Draft Environmental Impact Statement for 10 CFR Part 61 (NRC, 1981) to assess intruder scenarios. When evaluating protection of the inadvertent intruder, NRC assumed that active institutional controls would be maintained for 100 years following permanent closure (10 CFR 61.59(b)).

Additional guidance on intruder analysis can be found in NUREG–0782 (NRC, 1981, Vol. 2, Chapter 4), NUREG–1200 (NRC, 1988), and NUREG/CR–4370 (Oztunali and Roles, 1986). Performance assessment modeling approaches are discussed in Section 4 of this review plan, and additional guidance for developing performance assessment and dose assessment models can be found in NUREG–1573 (NRC, 2000b) and NUREG–1757 (NRC, 2003b). Specific guidance on the period for active institutional controls is provided in Section 4.1.1.1, and the influence of regional practices on scenario identification is discussed in Sections 4.1.1.3 and 4.1.1.4. Protection of individuals during operations is discussed in Section 6, and site stability is discussed in Section 7 of this review plan.

5.1 Areas of Review

In reviewing the intruder protection system proposed by the U.S. Department of Energy (DOE), reviewers should consider the operations, procedures, materials, barriers, and structures designated to provide this protection. Active protection systems may be effective during a 100-year period of institutional control, but given the long time periods considered in performance assessment following permanent closure of the facility, reviewers may need to consider the performance of engineered and natural systems as passive barriers to intrusion. A passive barrier is a barrier that may perform its intended functions without active monitoring and maintenance. The reviewer should take a risk-informed, performance-based approach to reviewing any site-specific intruder analysis and inadvertent intruder protection systems proposed by DOE, and the reviewer should evaluate the parameters used in the intruder analysis in the context of regional practices. This approach provides DOE with flexibility in analyzing intruder scenarios to demonstrate compliance with the performance objectives of 10 CFR 61.42.

5.1.1 Assessment of Inadvertent Intrusion

The reviewer should assess information provided by DOE regarding estimates of the potential dose to an inadvertent intruder. Because many intruder scenarios may be more simple and involve less integration than the public dose scenarios evaluated for compliance with 10 CFR 61.41, a more simplified analysis may be performed which would not be considered a traditional performance assessment. The review of the nominal case performance assessment is described in Section 4 of this review plan. The reviewer should evaluate the following information regarding inadvertent intrusion:

- Technical bases and associated analyses used to define the intruder scenarios. This should include aspects such as the behavior of the intruder, timing of the intrusion, and the exposure pathways simulated in the intruder analysis.

- Assumptions and parameters used in developing the intrusion assessment, characteristics of the intrusion event, how uncertainties are considered in the analysis, and resultant conditional doses for each intruder scenario. The assumptions in the intruder analysis should be consistent with past, current, and projected regional practices and the performance assessment (see Section 4).

5.1.2 Intruder Protection Systems

As discussed in Section 4.1.1.1, active institutional controls are limited to 100 years or less, but DOE may propose passive systems to protect from inadvertent intrusion. The reviewer should examine any intruder protection system proposed by DOE. This could include engineered barriers (caps, rock layers) or waste system placement and burial to reduce the potential for inadvertent intrusion (e.g., depth to waste). As specified in 10 CFR Part 61, intruder barriers should prevent or limit intrusion for 500 years for Class C waste. After 500 years, the activity of Class C waste would decay such that an inadvertent intruder would be protected if they contacted the waste. It would be expected that the service life for an intruder barrier for greater than Class C waste may need to be considerably longer and technical justification for long-term performance may be considerably more challenging. As discussed in Section 3.2.2 of NUREG-1573, service lives for engineered barriers, on the order of a few hundred years, are considered credible, if justified by adequate technical analyses and data (NRC, 2000b). The reviewer should review how the features of the engineered barriers and projected service lifetimes are incorporated in the intruder analysis. Depth to waste is an important consideration in defining intruder scenarios, because some scenarios may not be credible if the waste is generally inaccessible. The reviewer should review the projected depth to waste for the waste disposal system being evaluated.

5.1.3 Types of Scenarios Considered in the Intruder Analysis

Future human behavior cannot be accurately predicted over hundreds to thousands of years. To address this uncertainty, hypothetical intruder scenarios are designed to bound the exposure to the intruder, while avoiding speculation about future human activities. The regulations in 10 CFR 61.42 do not specify a particular scenario to be used for the demonstrating compliance. In developing intruder scenarios, it is anticipated that DOE will assume humans will continue normal land use activities, that are consistent with recent past (e.g., a few decades) and current regional practices, after active institutional controls are no longer enforced. DOE is not expected to provide probability estimates for the individual scenarios, but conditional doses should be estimated for each scenario considered in the inadvertent intruder analysis. To the extent that DOE has provided an analysis of various intruder scenarios, the reviewer should evaluate the site-specific scenarios using the guidance in Section 5.2. This may include one or more of the following scenarios.

5.1.3.1 Intruder-Resident Scenario

In this scenario, it is assumed that after the end of active institutional controls, an intruder (i.e., the resident intruder) inadvertently constructs a house at, and lives on, the waste disposal area. The reviewer should assess the location of the resident intruder relative to the waste disposal system, the behavior attributed to the intruder, and the timing of the intrusion. The reviewer should examine dose pathways assumed for this scenario (e.g., direct exposure, ingestion [drinking water, vegetables, soil], inhalation), and the parameters and calculations used to estimate intruder doses. The resident intruder may also be exposed to contaminated drill cuttings that resulted from installation of a well for domestic purposes (see Section 5.1.3.4).

5.1.3.2 Intruder-Agriculture Scenario

In this scenario, it is assumed that after the end of active institutional controls, a farmer lives on, and consumes food crops grown and animals raised on the disposal area. The reviewer should assess the location of the intruder relative to the waste disposal system, the behavior attributed to the intruder, and the timing of the intrusion. The reviewer should examine dose pathways assumed for this scenario (e.g., direct exposure, ingestion [drinking water, plant products, animal products, soil], inhalation), and the parameters and calculations used to estimate intruder doses. The reviewer should examine the extent to which the intruder analysis considers ground-disturbing activities by the farmer (e.g., plowing, spreading drill cuttings). Additional description of this scenario is provided in NUREG–0782 (NRC, 1981, Appendix G).

5.1.3.3 Intruder-Recreational Hunting/Fishing Scenario

In this scenario, a hunter/fisher is assumed to inadvertently visit the site, perhaps on a periodic basis, and consumes game and fish taken from the site. The reviewer should assess the behavior attributed to the intruder and the timing of the intrusion. The reviewer should examine dose pathways assumed for this scenario (e.g., direct exposure, inadvertent soil ingestion, inhalation, ingestion of fish and game), the parameters and calculations used to estimate intruder doses, and the time spent at the site.

5.1.3.4 Intruder-Driller Scenario

In this scenario, it is assumed that after the end of active institutional controls, a well is drilled into the waste disposal system. The well may be for domestic water use, irrigation, or the exploration or recovery of natural resources. If any other natural resources are identified (see Section 1.1.3.2), additional drilling scenarios may be proposed. In a drilling scenario, an acute intruder is assumed to be the person or persons who install the well and are exposed to drill cuttings during well installation. The reviewer should assess the behavior attributed to the intruder and the timing of the intrusion. The reviewer should examine dose pathways assumed for this scenario (e.g., direct exposure, inadvertent ingestion of soil, inhalation), the parameters and calculations used to estimate intruder doses, and the time spent to install the well. Additional description of this scenario is provided in NUREG/CR–4370 (Oztunali and Roles, 1986). Exposure of a resident or farmer to drill cuttings left on the land surface after the installation of a well would be considered under Section 5.1.3.1 or Section 5.1.3.2, respectively.

5.1.3.5 Intruder-Construction Scenario

In this scenario, it is assumed that after the end of active institutional controls, a construction project begins at the site with associated earthmoving activities. The reviewer should assess the behavior attributed to the intruder and the timing of the intrusion. The reviewer should examine dose pathways assumed for this scenario (e.g., direct exposure, inadvertent ingestion of soil, inhalation), and the time spent at the site. Additional description of this scenario is provided in NUREG–0782 (NRC, 1981, Appendix G).

5.1.3.6 Other Scenarios

There may be other, less common scenarios proposed on a site-specific basis. As with the previous scenarios, the reviewer should assess the behavior attributed to the intruder and the timing of the intrusion. The reviewer should examine dose pathways assumed for the scenario, the time spent at the site, and the parameters and calculations used to estimate intruder doses. The reviewer should assess whether the other intruder scenarios are appropriate and sufficiently conservative.

5.2 Review Procedures

The reviewer should evaluate the types of scenarios considered by DOE in the intruder analysis, and confirm that the scenarios considered are appropriate for the site. Specifically, the reviewer should:

- Verify that assumptions and parameters used in defining the exposed intruder, including location and behavior of the intruder, timing of the intrusion, and exposure pathways, are consistent with the current regional practices. For example, at a site with shallow water sources and low-strength surface geologic materials, local drilling companies may not typically be equipped to drill through buried, high-strength engineered materials. However, at a site with high-strength geologic materials (e.g., basalt) and deep water sources, drilling companies may be commonly equipped to drill through an underground engineered structure (inadvertently).

- Verify that assumptions and parameters used in defining the exposed intruder are consistent with the performance assessment review conducted under Section 4 of this review plan. For example, confirm that the same radionuclide inventories are used for both the performance assessment and the intruder analysis.

- The reviewer should assess that the selection of intruder scenarios by DOE considered wasteform and barrier degradation (e.g., it may be safe to rule out drilling for the first 1000 or 2000 years because of intruder barriers or wasteform characteristics, but drilling may become more plausible as the wasteform or barriers degrade).

- Verify that the time of intrusion assumed in the analysis produces the maximum dose. For example, an intrusion event at 100 years may produce the maximum dose from short-lived fission products but the maximum dose from the daughters of long-lived isotopes may occur long after 1000 years.

- Verify that the wasteform properties and the disposal facility design (including natural and engineered barriers designed to protect inadvertent intruders) considered in the intruder analysis are consistent with the performance assessment conducted by DOE and reviewed under Section 4 of this review plan.

- Confirm that DOE does not use the probability of an intrusion to reduce the potential consequences estimated in the intruder analysis.

- Evaluate active institutional controls proposed in the waste determination, and assess the time period for which DOE assumes they are effective.

- Verify that proposed passive protection measures are appropriately represented in conceptual and numerical models used to simulate long-term performance, for time periods that are consistent with the 500-year intruder barrier design specified in 10 CFR 61.52. In particular, evaluate whether degradation of intruder protection systems is appropriately considered in the intruder analysis.

- Verify that adequate technical basis is provided for parameters used in the intruder analysis, in particular for site-specific, regionally-based values that are less conservative than typical generic parameters.

- Verify that the area over which contaminated material is dispersed is appropriate for the scenario. For example, the area required to distribute contaminated soil and waste from the excavation of a foundation for a residence will be considerably larger than the area required to distribute contaminated drill cuttings.

- If a garden is assumed in the scenario, verify that the garden size is appropriate and consistent with regional practices. Verify that the garden size is consistent with the assumed yields of produce from the garden.

- Evaluate whether the DOE assessment of inadvertent intrusion provides reasonable assurance that an inadvertent intruder will be sufficiently protected, based on an understanding of assumptions and parameters of the analysis, characteristics of the intrusion event, and consideration of uncertainties in the analysis. Compare the intruder doses calculated in the intruder analysis to the 5 mSv/yr (500 mrem/yr) standard described in NRC (1981, Vol. 2, Section 4.5). Evaluate the DOE identification and summary of key assumptions and parameters that most strongly influence the dose results for the inadvertent intruder analyses.

5.3 References

Oztunali, O.I. and G.W. Roles. “Update of Part 61: Impacts Analysis Methodology, Methodology Report.” NUREG/CR-4370. NRC. 1986.

U.S. Nuclear Regulatory Commission (NRC). “Draft Environmental Impact Statement on 10 CFR Part 61 Licensing Requirements for Land Disposal of Radioactive Waste.” NUREG–0782. September 1981.

———. “Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility.” NUREG-1200. NRC. January 1988.

———. “Savannah River Site High-Level Waste Tank Closure: Classification of Residual Waste as Incidental.” Letter from W. Kane to R.J. Schepens, DOE. June 2000a.

———. “A Performance Assessment Methodology for Low-Level Radioactive Waste Disposal Facilities: Recommendations of NRC’s Performance Assessment Working Group.” NUREG-1573. October 2000b.

———. “NRC Review of Idaho Nuclear Technology and Engineering Center Draft Waste Incidental to Reprocessing Determination for Tank Farm Facility Residuals - Conclusions and Recommendations.” Letter from L. Kokajko to J. Case, DOE. June 2003a.

———. NUREG–1757, “Consolidated NMSS Decommissioning Guidance.” Vols. 1–3. NUREG-1757. September 2003b.

———. “Technical Evaluation Report for the U.S. Department of Energy, Savannah River Site Draft Section 3116 Waste Determination for Salt Waste Disposal.” Letter from L. Camper to C. Anderson, DOE. December 2005.

6 PROTECTION OF INDIVIDUALS DURING OPERATIONS

The performance objective for protection of individuals during operations is provided in 10 CFR 61.43. Specifically, the staff review should confirm whether design, operation, and closure of the facility will provide reasonable assurance that the radiation protection standards set out in 10 CFR Part 20 can be met. This includes doses both to workers and to a member of the public during operations. In addition, 10 CFR 61.43 includes requirements that every reasonable effort will be made to maintain radiation exposures as low as is reasonably achievable (ALARA). The U.S. Department of Energy (DOE) is self-regulating with respect to operational activities and uses the regulations in 10 CFR Part 835 "Occupational Radiation Protection" to set operational dose limits for workers and members of the public and to demonstrate ALARA. The waste criteria discussed in Section 2 of this review plan do not confer regulatory or statutory authority on the U.S. Nuclear Regulatory Commission (NRC) with regard to DOE operational activities.

In demonstrating that there is reasonable assurance that the 10 CFR Part 61.43 performance objectives can be met, DOE can reference the applicable portions of 10 CFR Part 20 and provide the corresponding requirement of 10 CFR Part 835. Given the role of NRC with respect to incidental waste activities, the portions of 10 CFR Part 20 which are relevant in this context are the dose limits for radiation protection of the public and workers during disposal operations, and not those requirements regarding general licensing, administrative, programmatic, or enforcement matters intended for NRC licensees. Therefore, the applicable portions of 10 CFR Part 20 are:

- 10 CFR 20.1101(d),
- 10 CFR 20.1201(a)(1)(i)
- 10 CFR 20.1201(a)(1)(ii)
- 10 CFR 20.1201(a)(2)(i)
- 10 CFR 20.1201(a)(2)(ii)
- 10 CFR 20.1201(e)
- 10 CFR 20.1206(e)
- 10 CFR 20.1207
- 10 CFR 20.1208(a)
- 10 CFR 20.1301(a)(1)
- 10 CFR 20.1301(a)(2)
- 10 CFR 20.1301(b)

These dose limits generally correspond to the dose limits in 10 CFR Part 835 and relevant DOE Orders and guidance which establish DOE regulatory and contractual requirements for DOE facilities and activities. On the basis of this equivalence, the reviewer need only to evaluate how the DOE regulations and limits would be implemented at the site. As required by the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA) (see appendix), NRC will monitor compliance with 10 CFR 61.43, as discussed in Section 10 of this review plan, for waste that is subject to the NDAA.

6.1 Areas of Review

The focus of this part of the staff review is on the operational dose limits identified by DOE and the commitments made to meet them. Releases of radioactivity in effluents from the facility are governed by the requirements of 10 CFR 61.41, as discussed in Section 4 of this review plan. Other doses are governed by 10 CFR 61.43, which references 10 CFR Part 20. The reviewer should determine what regulations and limits will be used to establish operational dose limits for any proposed facilities and activities, and what approaches and radiation protection programs will be used to ensure ALARA. The reviewer should evaluate estimated doses to both workers and members of the public during operations. Typically, the estimated dose to the public is calculated at the limit of active institutional controls (i.e., the fence line of the larger DOE site), but also includes members of the public who visit the site. As necessary, the reviewer should also examine selected portions of DOE operational documents to learn how DOE implements its worker protection program. For example, DOE may have radiation protection programs, documented safety analyses, or relevant access controls and training.

6.2 Review Procedures

It is anticipated that DOE will continue to reference the regulations and limits set forth in 10 CFR Part 835 to establish operational dose limits and to demonstrate ALARA for proposed waste management activities. The implementation of these commitments and compliance with the requirements and limits will be ensured through DOE's own regulations and assessed during NRC monitoring (see Section 10). The review for this section should therefore focus on DOE commitments to adhere to the appropriate regulations and descriptions of how the regulations are implemented with respect to the waste determination. Based on this assumption, the reviewer should perform the following procedures:

- Determine whether DOE has identified either 10 CFR Part 20 or 10 CFR Part 835 as the basis for its radiation protection programs and dose limits. If DOE has identified other limits, ensure that these regulations and limits provide protection from radiation exposure that is comparable to the NRC requirements in 10 CFR Part 20.

- Evaluate the appropriateness and adequacy of DOE estimates of doses that may be received by both workers and members of the public during operations with respect to the waste being evaluated, and determine whether the doses are less than those in 10 CFR 20 (e.g., 5 rem/yr for workers, 100 mrem/yr to a member of the public from sources other than effluents). Review the approaches and methods used to assure that the estimated doses will not be exceeded. The doses may be estimated by assessing the doses received from comparable activities at the site.

- Determine whether DOE has in place appropriate procedures and processes for ensuring that doses remain below applicable limits (e.g., a radiation protection program or safety analyses reports). Because DOE is a self-regulating Federal agency with a history of estimating and managing doses, the reviewer should apply the appropriate level of detail in reviewing this area (e.g., reviewing the assumptions made in accident analyses is typically not necessary).

- Verify that DOE will follow an ALARA philosophy. Confirm that management commitments, facility designs, and operations programs designed to control radiation exposure will be implemented so that doses are ALARA. As necessary, examine selected portions of DOE operational documents to learn how DOE implements its worker protection program.

- Review any additional measures to which DOE has committed to ensure that any radiation exposures will be ALARA.

7 SITE STABILITY, WASTE STABILITY, AND FACILITY STABILITY

7.1 Areas of Review

This section focuses on the stability of the proposed disposal site, including the potential for erosion, flooding, seismicity, and other disruptive processes. This section also addresses stability of the waste and engineered features of a disposal facility. The performance objectives for disposal site stability after closure are provided in 10 CFR 61.44, which states that the disposal facility must be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate, to the extent practicable, the need for ongoing active maintenance of the disposal site following closure.

The long-term performance of the disposal site depends on the stability of the natural environment of the site, the disposal facility design, and the physical stability of waste disposed of at the facility. Disruptive events that are part of the natural environment have the potential to significantly degrade waste isolation by directly or indirectly affecting the engineered barriers or the wasteform. In general, disposal sites should not be susceptible to erosion, flooding, seismicity, or other disruptive events to such a degree or frequency that waste isolation is compromised. In addition to natural site instabilities, waste and disposal facilities also may be subject to instabilities because of waste characteristics (e.g., differential settling caused by voids in the waste) or facility design (e.g., long term physical instability of vaults due to cracking). The relative importance of these processes may vary from site to site, and the level of detail of the review is expected to vary accordingly. Review areas are expected to include, but not necessarily be limited to, the technical areas described in 10 CFR 61.13(d) (i.e., erosion, mass wasting, slope failure, settlement of wastes and backfill, infiltration through covers over disposal areas and adjacent soils, and surface drainage of the disposal site).

7.1.1 Siting Considerations

The performance objective for site stability (10 CFR 61.44) requires, in part, that facilities be sited to achieve long-term stability. Although a waste determination may pertain to disposal in a facility that already has been sited (e.g., disposal of residual waste in tanks), the reviewer should review the siting considerations described in 10 CFR 61.50 because the siting considerations identify processes that may impact long-term disposal site stability. Siting considerations that may impact site stability include, but are not necessarily limited to, flooding, runoff from upstream drainage, erosion, water table fluctuation, discharge to surface waters on the disposal site, tectonic processes, slumping, landsliding, and weathering. The reviewer should evaluate the consistency of the disposal site with the siting considerations. If there is significant potential for site instability, the reviewer should evaluate the measures taken to assure waste isolation despite the potential site instabilities.

7.1.1.1 Flooding and Water Table Fluctuation

Flooding, ponding, and periodic immersion of waste due to water table fluctuation all can affect the stability of the waste and disposal facility by accelerating wasteform and barrier degradation. To assess the potential for flooding and immersion of the waste due to water table fluctuation, the reviewer should evaluate site-specific hydrologic data, as described in Section 1.1.3.5. In evaluating the potential for site flooding, the reviewer should evaluate rainfall intensity, the time of concentration of rainfall events, rainfall distributions, infiltration losses and surface runoff, and how these factors are considered in selecting probable maximum flood and the design basis flooding event. Additional guidance on reviewing information about flooding is provided in NUREG–1620 (NRC, 2003a, Section 3) and other U.S. Nuclear Regulatory Commission (NRC) guidance documents (NRC, 2005a, 2002).

To evaluate the potential for innundation of the waste by water table fluctuation, the reviewer should evaluate the historical record of water table depths in the area as well as information about the seasonal fluctuation of the depth of the water table. The reviewer should evaluate information about the wells from which the water table data were taken, including information about temporary surface features (e.g., paved areas on the surface near disposal units) that could artificially depress the water table elevation in wells near the proposed disposal site. In addition, for sites at which the waste may be disposed of near the zone of water table fluctuation, the reviewer should assess the potential rise in the water table due to potential increases in precipitation that could be caused by natural climate change during the 10,000–year performance period. If wastes are likely to be located in the zone of water table fluctuation during the performance period, the reviewer should examine the technical basis for the predicted effect of the periodic innundation of the waste on the stability of the wasteform and relevant engineered barriers. In general, if the waste is likely to be impacted by water table fluctuation, justification is required to support the conclusion that facility performance will be acceptable.

7.1.1.2 Surface Geologic Processes

Surface geologic processes such as erosion, mass wasting, slumping, and landsliding can have a significant effect on disposal site stability. The reviewer should assess the potential for significant geological surface processes by reviewing historical information about such processes in the area (e.g., historical records of landslides near the site) and by reviewing information about site geomorphology as described in Section 1.1.3.4.

The reviewer should evaluate the design of any engineered barriers proposed to provide long-term erosion protection. While active maintenance of erosion control systems may be assumed during a period of institutional controls (100 years or less; see Section 4.1.1.1), longer term erosion protection should rely on robust passive controls. To assess erosion control barriers, the reviewer should consider rock durability, gradation, cover design, stability calculations for the top slope, side slope, and apron for any cover, and other construction considerations that are important to the performance of the erosion control system. Additional guidance about reviewing the design of erosion control barriers is available in NUREG–1623 (NRC, 2002). As described in NUREG–1623 and NUREG–1620 (NRC, 2003a, 2002), a review of proposed erosion control measures also includes an assessment of the response of the engineered system to flooding and precipitation events. Specifically, erosion barrier designs should account for the selection of an appropriate design basis flood or rainfall event, control of gully initiation and gully development, and the occurrence of flow concentrations and drainage network development.

7.1.1.3 Seismicity

The reviewer should assess the potential for seismic impact to the site and proposed waste containment structures. For example, although earthquakes are not frequent at the Savannah River Site, the Charleston earthquake of 1886 had a magnitude estimate of M 7.3 with an epicenter approximately 144 km (90 mi) from the Savannah River Site (NRC, 2005b). Such history indicates the need to evaluate the seismic stability of the proposed waste containment structures and supporting soils. The reviewer should evaluate the potential for significant seismic activity by reviewing the historic seismic data in light of the most recent understandings of seismicity in the region. The evaluation should include recurrence intervals, magnitudes, and durations, as well as factors that contribute to peak ground acceleration such as underlying geologic structures, and the stratigraphy and lithologies of the site. The review also should include an evaluation of the predicted effects of seismic events on waste isolation, and a review of any aspects of the disposal plans designed to mitigate the potential effects of seismic events on waste isolation. Additional guidance on reviewing information related to seismic events is provided in NUREG–1804 (NRC, 2003b).

7.1.1.4 Other Processes

Other natural processes may affect the long-term stability of the disposal site. These processes can include biological processes such as biointrusion into waste or closure caps (e.g., by plant roots or burrowing animals), weather related hazards such as tornadoes and hurricanes, or other hazards such as fires. During the operations period and the period of active institutional controls, it is anticipated that DOE will have operational procedures (e.g., fire control) to mitigate the effects of these processes. For the period following the end of institutional controls, these processes should be considered on a case-by-case basis, depending on their potential to disrupt the waste isolation capabilities of the disposal site. In many cases involving waste buried at several meters depth, occasional surface events such as tornadoes and fires are not expected to have a significant effect on disposal facility stability; however, the potential effects on engineered barriers near the surface should be bounded and, if necessary, evaluated in greater detail.

7.1.2 Waste and Facility Stability

In addition to the stability of the natural site, compliance with the performance objective for disposal site stability depends on the stability of the waste and engineered barriers of the disposal facility. In general, some of the concerns regarding the stability of low-level waste are related to the stability of typical commercial Class A wastes such as contaminated lab trash, clothing, or plastics and are not expected to be relevant to waste determinations. However, other aspects of the stability of wastes described in 10 CFR 61.56(b), such as the structural stability of waste under the overburden expected after site closure, the effect of radiation and changing chemical conditions on the structural stability of the waste, the presence of free water in the waste, and the presence of void spaces in the waste (e.g., in abandoned equipment), may be pertinent to incidental wastes and should be reviewed. Similarly, the technical areas expected to affect disposal site stability described in 10 CFR 61.51, including (1) the design of covers to limit water infiltration, to direct water away from the waste, and to resist degradation by surface geologic and biotic processes; (2) the design of surface features to direct surface water drainage away from disposal units at velocities and gradients that will not result in erosion; and (3) the design of the disposal site to minimize the contact of percolating or standing water with wastes after disposal, are all expected to be relevant to an assessment of disposal facility stability in the context of a waste determination.

In addition to the stability concerns specifically described in 10 CFR 61, the reviewer should also evaluate the potential for structural degradation of wasteforms and containment structures (e.g., tanks, vaults) more specific to waste determinations (see Section 4.3.3). For example, in many cases, waste may be mixed with or encapsulated in a cementitious material. If so, the reviewer should evaluate the potential for structural degradation due to leaching, sulfate attack, carbonation, corrosion of embedded metals, or by cracking caused by differential settling or seismic activity. Additional guidance about evaluating the degradation of cementitious materials is available in NUREG/CR-5542 (Walton et al., 1990) and NUREG/CR-5666 (Clifton and Knab, 1989). Degradation of the wasteform and containment facilities can increase penetration of groundwater into the waste and can provide enhanced paths for release of radionuclides. Typically, there are large uncertainties associated with predictions of long-term wasteform degradation and facility stability, and simplified analyses may be used to bound the expected degradation (and the effects of this degradation on performance) over long time periods.

7.2 Review Procedures

To evaluate compliance with the site stability performance objective (10 CFR 61.44), the reviewer should assess the expected occurrence of the disruptive processes described in Section 7.1, and evaluate the potential effects of the disruptive processes on disposal facility performance. The level of detail of the review should depend on the potential for significant site instability (e.g., flooding, erosion, seismicity) and the degree to which disruptive processes could affect disposal facility performance. If the disposal site has a significant potential for instability, the reviewer should perform a detailed review of the processes that could cause instability and the elements of the proposed facility designed to ensure waste isolation in light of the potential instabilities. If, on the other hand, there is little potential for significant disposal site instability, then the reviewer should conduct a simplified review focusing on the technical bases for this conclusion.

This part of the review is limited to an assessment of site stability. However, processes that cause significant disposal site instability are expected to affect the long-term performance of the disposal site. For example, increased infiltration due to disruption of a closure cap by biointrusion or erosion may have significant effect on radionuclides release and may need to be considered in the performance assessment (see Section 4). Similarly, structural degradation of wasteforms or intruder barriers would be expected to have a significant effect on the plausibility of potential inadvertent intruder scenarios (see Section 5). Thus, the reviewer should coordinate the review of site stability with the review of compliance with other performance objectives of 10 CFR Part 61, Subpart C. The reviewer should perform the following procedures:

- Confirm that the evaluation of flooding scenarios has accounted for flooding of adjacent streams, as applicable, and localized flooding of drainage channels and protective features. The reviewer should verify that DOE has properly used the probable maximum precipitation/probable maximum flood in determining the design flood event (NRC, 2002, Appendix D; NRC, 2003a, Section 3.2.2).

- Confirm that the probable maximum flood is consistent with, but not based solely on an extrapolation of the historic flood record. Ensure that the technical basis for the probable maximum flood includes calculations based on the most severe reasonably possible rainfall events that could occur as a result of a combination of the most severe meteorological conditions occurring over a watershed (probable maximum precipitation).

- If the historic maximum regional floods exceed or closely approximate the proposed probable maximum flood estimates, the reviewer should perform a detailed evaluation to determine the basis for the estimates. The reviewer should compare basin lag times, rainfall distributions, soil types, and infiltration loss rates to determine if there is a logical basis for the probable maximum flood values being less than historic floods.

- If DOE uses detailed computer models to support its design flood determinations, the staff should confirm the adequacy of the various input parameters to the model, including, but not limited to, the following: drainage area, lag times and times of concentration, design rainfall, incremental rainfall amounts, temporal distribution of incremental rainfall, and runoff/infiltration relationships.

- Determine whether the waste is likely to be located in the zone of water table fluctuation during the 10,000 year performance period. Specifically, the reviewer should:

  – Evaluate the historical record of water table depths in the area as well as information about seasonal fluctuations of the depth of the water table. The reviewer should examine precipitation data corresponding to the period of historical water table data to determine if the water table data were taken during an adequately representative period of precipitation (e.g., that well data do not represent a period of relatively low precipitation).

  – Ensure that the assessment of the location of the waste with respect to the water table is not affected by temporary surface features (e.g., paved areas on the surface near disposal units) that could artificially depress the water table elevation in wells near the proposed disposal site.

  – Determine whether the waste may be located in the zone of water table fluctuation during the 10,000 year performance period because of potential changes in precipitation due to natural climate change.

  – If the waste is likely to be located in the zone of water table fluctuation during the review period, the reviewer should examine the technical basis for the predicted stability of the disposal site and wasteform in detail and ensure that the potential effects of water table fluctuation on disposal site stability have been adequately represented or bounded (e.g., effects on wasteform degradation, barrier degradation, sudden radionuclide releases due to episodic submersion of waste).

- Verify that the analysis of potential erosion at the site includes an assessment of floods, flood velocities, design features, and rock durability that is comparable to those described in NUREG–1623 (NRC, 2002, Appendix D).

- If erosion is expected to have a significant effect on site stability, then evaluate whether the erosion protection design is sufficient to avoid the need for ongoing active maintenance at the site. Specifically, the reviewer should determine the adequacy of the following technical areas, as appropriate to the proposed design:

  - Treatment of the banks of natural channels, including armoring and designs to place riprap as a protective measure against flood erosion;

  - Stability estimates for the top slope, side slopes, and apron, including design flow rate, depth of flow, design discharge, angle of repose, specific gravity, rock sizes, and other parameters;

  - The design of diversion channels, outlets, and discharge areas, including the parameters used to define the erosion protection such as flow rates, flow depths, shear stresses, erosion protection (riprap), rock size, and the effects of sediment accumulation;

  - Rock durability testing of proposed rock sources, especially with regard to clay content, to ensure that durable rock will be used;

  - Determination of allowable shear stresses and permissible velocities for any soil or vegetative cover, including an assessment of the cover performance in a degraded state;

  - Information on types of vegetation proposed and their abilities to survive natural phenomena, and expected natural vegetation progression (e.g., grass cover being replaced by tree cover over time);

  - Construction considerations such as plans, specifications, inspection programs, and quality assurance/quality control programs to assure that adequate measures are being taken to construct the design features according to accepted engineering practices; and

  - Information, analyses, and calculations of input parameters to models used.

- Verify that the description of the potential for seismic events is derived from the historical record, paleoseismic studies, or geological analyses. The reviewer should evaluate recurrence intervals, and magnitudes of past events and determine whether the reported potential for seismic events is consistent with the historical record.

- Determine whether seismic events that are likely to occur during the performance period are likely to have a significant impact on the stability of the disposal facility by causing structural damage to wasteforms or engineered barriers (e.g., cracking of grouted wasteforms or vaults).

- Assess the potential disruption of wasteforms or engineered barriers (e.g., caps designed to limit infiltration) by intrusion of roots or burrowing animals by evaluating biological information relevant to the site. If populations of burrowing animals are identified, or if the site is expected to revert to forests during the performance period, the reviewer should determine whether disposal site features designed to limit the effects of biointrusion are adequate to maintain site stability.

- Determine whether disruptive events such as hurricanes, tornadoes, and fires could cause significant site instability, and, if so, what aspects of the facility are designed to maintain site stability if the disruptive events occur.

- Verify that the waste will remain structurally stable under the overburden expected after site closure. Specifically, the reviewer should ensure that the effects of radiation and any changes expected in chemical conditions (e.g., because of infiltrating groundwater or corrosion of embedded metal) will not cause instability of the waste as emplaced after closure. The reviewer also should verify that the presence of free water in the waste will be minimal (e.g., less than 1% by volume) and that there will not be significant void spaces in the waste (e.g., inside abandoned equipment) that could cause differential settling of the waste or engineered barriers.

- Verify that covers have been designed to limit water infiltration and to direct infiltrating water away from the waste. The reviewer also should verify that any surface features of the disposal facility have been designed to direct surface water drainage away from disposal units at velocities and gradients that will not result in erosion.

- If wastes will be mixed with or encapsulated in cementitious material, the reviewer should determine the potential for significant structural degradation due to leaching, sulfate attack, carbonation, or corrosion of embedded metals. Because of the large uncertainty in potential degradation though these processes, the reviewer should use simplified analyses to bound the expected degradation during the performance period. If the reviewer determines that there is significant potential for structural degradation of the wasteform or cementitious engineered barriers because of these processes, the potential effects on radionuclides release or plausible inadvertent intruder scenarios should be represented or bounded in the performance assessment (see Section 3) or inadvertent intruder analysis (see Section 4).

7.3 References

Clifton, J.R., Knab, L.I. "Service Life of Concrete." Final Report. NUREG/CR–5466. September 1989.

U.S. Nuclear Regulatory Commission (NRC). NUREG–1623, "Design of Erosion Protection for Long-Term Stabilization." Final Report. September 2002.

———. "Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978." NUREG–1620. June 2003a.

———. "Yucca Mountain Review Plan." NUREG–1804. July 2003b.

———. "Consolidated NMSS Decommissioning Guidance. Updates to Implement the License Termination Rule Analysis." Draft Report for Comment. NUREG–1757, Supplement 1. September 2005a.

———. "Final Safety Evaluation Report on the Construction Authorization for the Mixed Oxide Fuel Fabrication Facility at the Savannah River Site, South Carolina." NUREG–1821. March 2005b.

Walton, J.C., Plansky, L.E., Smith, R.W. NUREG/CR–5542, "Models for Estimation of Service Life of Concrete Barriers in Low-Level Radioactive Waste Disposal" Final Report. September 2002.

8 QUALITY ASSURANCE PROGRAM

Quality assurance, in the context of this review plan, comprises all of the planned and systematic actions necessary to provide adequate confidence that the applicable incidental waste criteria can be met. An adequate quality assurance program is essential to ensuring that the key information relied upon to make incidental waste determinations is correct and accurate.

The purpose of this review is to verify that the U.S. Department of Energy (DOE) has applied quality assurance measures to its data collection, analyses, waste determinations, and performance assessments. This review plan provides risk-informed and performance-based approaches for evaluating quality assurance information. The adequacy of quality assurance measures will be determined using a sample of analyses selected based on their risk significance, and the adequacy of the quality assurance measures will be determined based on impacts to performance of any identified deficiencies. For example, a quality assurance deficiency of a risk significant element of the performance assessment may have a minor, moderate, or major impact on the results of the analysis. Both the severity and the pervasiveness of deficiencies should be considered by the reviewer when evaluating the adequacy of quality assurance measures. The reviewer should use this guidance in reviewing quality assurance measures applied to DOE waste determinations and performance assessments. Section 17.6 of NUREG-1757, Volume 1, Revision 1 provides U.S. Nuclear Regulatory Commission (NRC) regulatory requirements pertinent to quality assurance as applied to decommissioning sites (NRC, 2003). These requirements may be considered by the reviewer when evaluating DOE's quality assurance program as applied to the waste determination.

8.1 Areas of Review

The NRC staff review should evaluate a sample of the analyses associated with Areas of Review identified in Sections 2–7 of this review plan. The analyses should be selected based on the areas with high or medium risk with regard to meeting the performance objectives of 10 CFR Part 61, Subpart C and other applicable criteria. The risk importance of an analysis is likely to vary from facility to facility.

8.2 Review Procedures

8.2.1 Data Validity Review Procedures

The reviewer should examine the data used to support waste determinations and performance assessments to determine whether (1) the data are traceable to their sources through all calculations and data reductions and transparent in their use, and (2) the data have been obtained or qualified under an acceptable quality assurance program, such as an NRC-approved quality assurance program developed to meet the requirements of 10 CFR Part 50, Appendix B, or are otherwise documented and validated. Specifically, the reviewer should ensure the following:

- Data are identified in a manner that facilitates traceability to associated documentation back to the source and clearly identifies qualification status (e.g., qualified, unqualified, or accepted such as a physical constant). Traceability is the ability to trace the history, application, or location of an item and like items or activities by means of recorded identification.

- When changes are made affecting data identification (e.g., category or use/application), the changes are made in a manner that preserves traceability.

- Data used as direct input to scientific analysis or performance modeling are qualified or are validated by other comparable methods.

- If data are not collected under an acceptable quality assurance program, the data are qualified by one or more of the following: equivalent quality assurance program, corroborating data, confirmatory testing, or peer review (NRC, 1988).

- Documentation regarding data traceability and qualification is transparent and identifies the principal lines of investigation considered. A document is transparent if it is sufficiently detailed as to purpose, method, assumptions, inputs, conclusions, references, and units so that a person technically qualified in the subject can understand the document and ensure its adequacy without recourse to the originator.

- The data reduction process is described in detail sufficient to allow independent reproducibility by another qualified individual. Data reduction includes processes that change the form of expression, quantity of data or values, or number of data items. Verify that data reduction inputs, outputs, and computational methods are documented.

8.2.2 Software Selection and Development Review Procedures

The reviewer should assess the software used by DOE in the waste determination and performance assessment to determine whether: (1) the software has been endorsed for use by the NRC, or (2) DOE has demonstrated that the software adequately represents the processes or systems for which it is intended. The reviewer should evaluate whether the software development and approaches to validation of the software are planned, controlled, and documented. Planning for validation identifies the validation methods and validation criteria used.

The reviewer should assess controls applied to software to ensure that the software supporting waste determinations or performance assessments is qualified for use and has been developed, tested, and controlled under suitable conditions.

Specifically, the reviewer should ensure the following:

- Software has been endorsed by NRC for use in licensing activities. If the software has been endorsed, then the reviewer would, in general, not need to exercise the reviewer procedures specific to software quality assurance that follow.

- Software performs intended functions, provides correct solutions, and does not cause any adverse unintended results.

- Software verification and validation activities were planned, documented, and performed for each item of software.

- Software that was verified and validated and was subsequently changed has undergone additional verification and validation, and documentation of the additional verification and validation has been developed.

- The software development and maintenance process proceeded in a planned, traceable, and orderly manner, using a defined software life-cycle methodology.

- A software configuration management system has been established.

- Requirements controlling software procurement and services are established to assure proper verification and validation support, software maintenance, configuration control, and performance of software audits, assessments, or surveys. Requirements for suppliers reporting of software errors to the purchaser and, as appropriate, the purchasers reporting of software errors to the supplier are identified.

- If a defect was identified in software that adversely affects the results of previous application of the software, the condition adverse to quality was documented and controlled.

8.2.3 Analysis Review Procedures

The reviewer should assess the analysis to determine that the analysis was transparently documented, the objective and use of the software are described, and the software was not used outside of the range of its intended functions. Specifically, the reviewer should ensure that:

- Definition of the objective (intended use) of the software has been provided;

- The description of the conceptual model implemented in the software is clear;

- The software has not been used in a manner that is inconsistent with the conceptual model implemented in the software;

- Identification of inputs to the software and their sources has been provided;

- Discussion of mathematical and numerical models that are used in the software is provided, including governing equations, formulas, algorithms, and their scientific and mathematical bases;

- Associated software used, computer calculations performed, and basis to permit traceability of inputs and outputs have been identified;

- Discussion of initial and boundary conditions is provided;

- Model limitations (e.g., data available for model development, valid ranges of model application, spacial and temporal scaling) are discussed;

- Execution of software is appropriate with the various sources of uncertainties (i.e., conceptual model, mathematical model, process model, system model, parameters).

8.3 References

U.S. Nuclear Regulatory Commission (NRC). "Generic Technical Position on Qualification of Existing Data for High-Level Nuclear Waste Repositories." NUREG–1298. Washington, DC. February 1988.

———. "Consolidated NMSS Decommissioning Guidance." Vols. 1-3. NUREG-1757. Washington, DC. September 2003.

9 DOCUMENTING THE RESULTS OF THE REVIEW

9.1 General Approach to Documenting Waste Determination Reviews

As described in the U.S. Nuclear Regulatory Commission's (NRC) implementation plan for waste determination reviews conducted under the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA) (NRC, 2005a), the general approach to be used by the NRC staff will be similar to previously completed waste-incidental-to-reprocessing (WIR) reviews (NRC, 2000, 2002, 2003). Reviews not conducted under the NDAA will be conducted in a similar manner. As discussed in Section 2, however, due to differences between the criteria in the NDAA and those used in previous NRC reviews, there may be some technical differences in the reviews. This section of the review plan provides guidance on the process for conducting and documenting a review.

9.2 Request for Additional Information

The first step in the review process will be the U.S. Department of Energy's (DOE's) submittal of a waste determination and supporting documentation, including a performance assessment if necessary. Using the guidance described in Sections 1–8 of this review plan, the NRC staff will review whether DOE's assumptions, analyses, data, documentation, modeling, and conclusions are technically adequate, accurate, and in accordance with the appropriate waste criteria. If sufficient information is not provided for the reviewer to be able to determine that there is reasonable assurance that the waste criteria can be met, or if the reviewer has questions about the information provided by DOE, the NRC staff should develop a Request for Additional Information (RAI). A RAI is a list of questions for which the NRC staff needs responses from DOE in order to be able to complete its review. The staff's RAI should be risk-informed and focus on those areas that are most likely to impact the staff's conclusions. Also, the staff's goal should be for the RAI to be as complete as possible so that only one RAI is needed. In addition to responding to the specific questions raised in the RAI, DOE may decide to revise the waste determination itself, or the supporting documentation or modeling, based on NRC's questions and comments. If the information provided by DOE in its initial submittal is sufficient for the reviewer to determine whether there is reasonable assurance that the applicable waste criteria can be met, then the staff does not necessarily need to prepare an RAI and can prepare its Technical Evaluation Report (TER) (see Section 9.3)

9.3 Technical Evaluation Report

The TER documents the NRC staff's analyses and conclusions for a specific waste determination. The TER should include descriptions of DOE's approach, what was reviewed by the staff, the assumptions made in conducting the review, and the conclusions as to whether there is reasonable assurance that each applicable waste criterion can be met (see Sections 2-7). The amount of discussion in the TER for a specific area should be commensurate with its importance to NRC's conclusions. Examples of areas typically covered in a TER are waste inventory, identification of highly radioactive radionuclides, infiltration, wasteform degradation, near field transport, and hydrology. Specific TER sections may be developed as necessary to evaluate those aspects that are most significant for a specific waste determination. The TER may also include, in an appendix, recommendations for DOE's consideration; the purpose of the recommendations is to communicate actions that DOE might consider in order to further improve its waste management approach, and do not need to be implemented in order for the applicable waste criteria to be met.

For waste determination reviews conducted under the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA) (see Section 2), the TER should also identify the factors that are important to assessing compliance with 10 CFR Part 61, Subpart C. These factors will be one aspect of the NRC's monitoring role under the NDAA for a particular waste determination (see Section 10). An example of such a factor is the oxidation rate of the concrete used to stabilize a wasteform that could affect the release rates of certain radionuclides and therefore the possible doses. Because NRC does not have a similar monitoring role at Hanford or West Valley, the TERs for these sites do not need to identify the factors that are important to assessing compliance with 10 CFR Part 61, Subpart C.

9.4 Public Availability and Project Numbers

The Commission has directed the staff to ensure that the technical basis for its decisions regarding waste determination reviews under the NDAA are as "transparent, traceable, complete, and as open to the public and interested stakeholders as possible" (NRC, 2005b). To fulfill that direction, the documents associated with DOE's waste determinations and NRC's reviews should be made publicly available, both for reviews that are being conducted for sites under the NDAA and those that are not. This includes the waste determinations, supporting references, NRC's RAI, DOE's RAI responses and supporting references, meeting summaries, TERs, and any other relevant documents submitted by DOE or issued by NRC. One exception may be documents that DOE cannot publicly release because of security concerns. For discussion of public availability of reports related to monitoring under the NDAA, see Section 10.
For ease of finding and obtaining documents, the NRC staff has established project numbers for incidental waste activities at the sites, as follows: Savannah River Site is PROJ0734, Idaho National Laboratory is PROJ0735, Hanford is PROJ0736, and West Valley is POOM-32. These project numbers should be entered into the "Docket Number" field in NRC's Agencywide Documents Access and Management System (ADAMS).

9.5 References

NRC. "Savannah River Site High-Level Waste Tank Closure: Classification of Residual Waste as Incidental." Letter from W. Kane to R.J. Schepens, DOE. June 2000.

———. "NRC Review of Idaho National Engineering and Environmental Laboratory Draft Waste Incidental to Reprocessing Determination for Sodium-Bearing Waste - Conclusions and Recommendations." Letter from J. Greeves to J. Case, DOE. August 2002.

———. "NRC Review of Idaho Nuclear Technology and Engineering Center Draft Waste Incidental to Reprocessing Determination for Tank Farm Facility Residuals - Conclusions and Recommendations." Letter from L. Kokajko to J. Case, DOE. June 2003.

———. "Implementation of New U.S. Nuclear Regulatory Commission Responsibilities Under the National Defense Authorization Act of 2005 in Reviewing Waste Determinations for the U.S. Department of Energy." SECY-05-0073. April 2005a.

———. "Staff Requirements - SECY-05-0073 - Implementation of New U.S. Nuclear Regulatory Commission Responsibilities Under the National Defense Authorization Act of 2005 in Reviewing Waste Determinations for the USDOE." SRM-SECY-05-0073. June 2005b

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10 MONITORING

Paragraph (b)(1) of Section 3116 of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA) (see appendix) requires that the U.S. Nuclear Regulatory Commission (NRC) "...in coordination with the covered State, monitor disposal actions taken by the Department of Energy...for the purpose of assessing compliance with the performance objectives set out in subpart C of part 61 of title 10, Code of Federal Regulations." The NDAA requires that the NRC report any noncompliance to Congress, the State, and the U.S. Department of Energy (DOE) as soon as practicable after discovery of the noncompliant conditions and states that NRC's monitoring is subject to judicial review. However, the NRC does not have regulatory or enforcement authority over DOE. The NDAA applies only to the States of South Carolina and Idaho, and these are the States in which NRC would monitor DOE's disposal of non-HLW. NRC does not have a monitoring role at Hanford because Washington is not included as a covered State in the NDAA.

For West Valley, the NRC license is currently in abeyance while DOE completes its responsibilities under the West Valley Demonstration Project Act (WVDPA). The WVDPA also requires that NRC establish decommissioning criteria for the site. Those criteria were published by NRC in 2002 (NRC, 2002) and included criteria for determining whether certain waste disposed of on site is incidental waste; however, NRC does not have regulatory or enforcement authority over DOE under the WVDPA. If the license is reinstated and responsibility for the entire site returns to the licensee (the New York State Energy Research and Development Authority [NYSERDA]), NRC will retain the same monitoring responsibilities that it has for other licensees under the Atomic Energy Act with respect to ensuring that the site meets all applicable regulatory requirements. Therefore, the West Valley site is not included in the following discussion of monitoring.

10.1 General Monitoring Approach

The objective of NRC's monitoring is to assess whether DOE's disposal actions are in compliance with 10 CFR Part 61, Subpart C. Subpart C contains a General Requirement (10 CFR 61.40) and requirements for protection of the general population from releases of radioactivity (10 CFR 61.42), protection of individuals from inadvertent intrusion (10 CFR 61.42), protection of individuals during operations (10 CFR 61.43), and stability of the disposal site after closure (10 CFR 61.44). Each of these areas must be assessed during monitoring, as discussed below in Sections 10.3.1 through 10.3.5. The NRC staff does not intend to monitor all aspects of DOE's waste disposal but rather only those that may affect whether these performance objectives can be met.

NRC will conduct its monitoring in a risk-informed and performance-based manner. The specific areas monitored will depend significantly on the findings of the consultative technical review as documented in the Technical Evaluation Report (TER) (see Section 9). During the consultative technical review, the reviewers should identify those factors that are important to assessing compliance with 10 CFR Part 61, Subpart C. For example, the TER may identify areas such as wasteform degradation or infiltration rates as important parameters with respect to whether or not the disposal approach can meet the requirements of Subpart C. In addition, the scope of the monitoring may depend on the conservatism in DOE's analysis. If DOE uses assumptions that have been reviewed by the NRC staff and are found to be reasonably conservative or well supported by adequate technical bases, then those areas may not need to be monitored to the same extent. However, staff should still remain aware of the implementation of DOE's waste management approach and any developments that may challenge the validity of DOE's assumptions or analyses.

Monitoring to validate DOE assumptions may be required for a variety of reasons; for example, the assumption may not have been conservative and monitoring is needed to ensure that field conditions do not contradict the assumption, or the assumption may not have adequate supporting information and monitoring is needed to ensure that the assumption is correct. This monitoring could take the form of verifying the assumption by reviewing site monitoring reports or other environmental reports, reviewing additional or revised modeling performed by DOE, or other related information (e.g., further analytical research) that may support or refute the assumption. Relevant new information should be evaluated by NRC for its potential effect on whether DOE's disposal actions are in compliance with the performance objectives of 10 CFR Part 61, Subpart C.

It is important to note that the factors listed in the TER may not comprise an all-inclusive list, and that the number or types of areas monitored may change as more is learned about the disposal methods or as DOE's disposal plans proceed. For example, if sampling of the inventory is given as a factor that is important to assessing compliance, it may be that once the sampling phase of the waste treatment approach is complete, this factor would no longer need to be monitored. As another example, additional DOE or NRC analysis (e.g., performance assessment, groundwater modeling, or sensitivity/uncertainty analysis) could indicate that an area is in fact not important to meeting the performance objectives of 10 CFR Part 61, Subpart C. In this case, that area could be removed from the monitoring plan if there is sufficient evidence supporting such a conclusion. Alternatively, as performance assessment or other modeling is refined and revised, an area not previously identified in the TER may be shown to be important to assessing compliance. For these reasons, the NRC staff performing the monitoring should remain aware of revisions to DOE's modeling or disposal plans and review the effects of any changes on the predicted doses.

10.2 Development and Implementation of the Monitoring Plan

DOE should use the factors identified in the TER to develop a monitoring plan. DOE should develop the monitoring plan because it is the agency that is most cognizant of the site and of the activities that DOE already plans to include in its waste management approach (e.g., environmental monitoring methods and locations, research plans to develop site-specific distribution coefficients). NRC staff, in coordination with the State, will then review the monitoring plan to determine whether it satisfactorily addresses the factors identified in the TER and any other areas that need to be monitored for the purpose of assessing compliance. If it does not, NRC and the State should work with DOE to revise the monitoring plan as appropriate. Once the final monitoring plan is complete, the NRC staff will use the plan to assist in assessing whether DOE's disposal actions are in compliance with 10 CFR Part 61, Subpart C. The final monitoring plan should be made publicly available in the Agencywide Documents Access and Management System (ADAMS).

Monitoring is to be conducted in coordination with the State, as required by the NDAA. The State has specific regulatory authority at the DOE site and the monitoring plan may include areas already regulated by the State. If so, the NRC staff should work with the State to ensure that monitoring is as effective and efficient as possible. For example, the TER may indicate that each batch of waste should be sampled to verify that certain radionuclide inventories are not exceeded. It may be that the State requires more or less frequent sampling than that indicated in the monitoring plan. In that case, the NRC staff and the State should work together to establish a mutually acceptable sampling frequency that satisfies both NDAA and State requirements.

NRC staff and State representatives may conduct individual or joint monitoring visits to the sites. These site visits may include technical meetings with DOE, review of documentation, observation of DOE's disposal actions, or the performance of other relevant activities.

NRC staff should develop annual NDAA monitoring reports to document NRC's monitoring activities for the Savannah River Site and for Idaho National Laboratory. These reports will present relevant information such as areas monitored by NRC, activities undertaken to perform such monitoring, any noncompliance reports issued, and the conclusions reached by the staff. Draft monitoring reports should be provided to the State for review and comment prior to finalization. The final monitoring report should be made publicly available in ADAMS. In addition to the annual report, the staff should develop reports documenting any site visits or important conclusions reached during meetings with DOE or the State regarding monitoring.

10.3 Assessing Compliance with 10 CFR Part 61, Subpart C

The NRC staff should use the final monitoring plan to assess whether DOE's disposal actions are in compliance with 10 CFR Part 61, Subpart C. As the waste management activities proceed, NRC staff should remain aware of whether DOE is carrying out the activities described in the monitoring plan. NRC staff may confirm this by a variety of methods, including site visits, technical meetings with DOE, and document reviews. If DOE is not carrying out the activities described in the monitoring plan and NRC concludes that this could result in noncompliance with 10 CFR Part 61, Subpart C, then the staff should develop a noncompliance report, as described in Section 10.4. Because NRC does not have regulatory or enforcement authority over DOE, it is the role of Congress, the State, and DOE to determine what, if any, actions will be taken in response to a noncompliance report.

10.3.1 General Requirement

The regulations in 10 CFR 61.40 require that the disposal facilities must be sited, designed, operated, closed, and controlled after closure so that reasonable assurance exists that exposures to humans are within the limits established in the performance objectives in 10 CFR 61.41 through 10 CFR 61.44. In general, this requirement is satisfied when the other performance objectives are met, as described below.

10.3.2 Protection of the General Population

The regulations in 10 CFR 61.41 require that doses to a member of the public must not exceed an annual dose equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ. The NRC has stated that using 0.25 mSv/yr (25 mrem/yr) total effective dose equivalent (TEDE) is the preferred method for calculating whether this limit has been met (NRC, 1999, 2005). The regulations in10 CFR 61.41 also require that releases of radioactivity in effluents to the general environment should be as low as is reasonable achievable (ALARA). In order to monitor this performance objective, the NRC staff should use two approaches: (1) monitoring of DOE's assumptions and analyses, and (2) environmental and performance indicator monitoring. Performance indicators are types of information that can be observed that may establish the performance of the facility prior to observing the actual release of contaminants. For example, increasing liquid saturation values under an engineered cap designed to limit infiltration of water to the waste may be an indicator that the engineered cap is not functioning as designed. The technical review of the waste determination, as documented in the TER, will identify DOE assumptions and analyses that are important to ensuring that the 0.25 mSv/yr (25 mrem/yr) limit can be met (see Section 4). NRC staff should monitor those areas to assess whether the assumptions remain valid and whether any changes in the analyses have resulted in changes in estimated doses. For environmental monitoring, staff should review relevant site monitoring reports, as well as any other related information, such as State documents. This information should be used to confirm that the environmental monitoring is not detecting unacceptable releases of radionuclides from the disposal facility. The staff may also be able to use this information to evaluate performance indicators, such as early detection of a highly mobile non-radioactive species (e.g., nitrate) that can be traced to a particular disposal facility and may indicate premature degradation of facility performance.

To assess compliance with the ALARA requirement of 10 CFR 61.41, staff can base its monitoring on the analysis in the TER regarding whether highly radioactive radionuclides will be removed to the maximum extent practical and whether the waste has been stabilized in a manner to minimize radionuclide release, which is essentially equivalent to meeting the intent of ALARA (see Section 3). If DOE's waste management approach changes from the approach described in the waste determination and analyzed in the TER, staff should re-assess whether the new approach meets the intent of ALARA.

10.3.3 Protection of Individuals from Inadvertent Intrusion

The regulations in 10 CFR 61.42 require that the design, operation, and closure of the disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed. To assess compliance with this performance objective, the NRC staff should use the dose limit of 5 mSv (500 mrem) provided in the Draft Environmental Impact Statement for 10 CFR Part 61. The technical review of the waste determination, as documented in the TER, will identify DOE assumptions and analyses that are important to ensuring that the 5 mSv (500 mrem) limit can be met (see Section 5). NRC staff should monitor those areas to assess whether the assumptions remain valid and whether any changes in DOE's analyses have resulted in changes in estimated doses.

10.3.4 Protection of Individuals During Operations

The regulations in 10 CFR 61.43 require that operations at the disposal facility must be in compliance with the radiation protection requirements of 10 CFR Part 20, and that radiation exposures must be ALARA. In general, the NRC staff considers DOE radiation protection requirements in 10 CFR Part 835 and relevant DOE Orders and guidance to be equivalent to the worker protection requirements in 10 CFR Part 20 (see Section 6). To monitor this performance objective, the staff should review DOE relevant reports on worker doses for the facility, such as incident reports or annual site worker dose reports, to assess whether the doses are less than those in 10 CFR Part 20 and are ALARA.

For doses to members of the public during operations, staff should review site reports and other relevant documents to assess whether effluent releases from the waste disposal site would result in a dose greater than 0.25 mSv/yr (25 mrem/yr). The staff also should review records to ensure that members of the public do not receive doses in excess of 1 mSv/yr (100 mrem/yr) from non-effluents (e.g., direct gamma) resulting from all operations at the larger DOE site.

10.3.5 Stability of the Disposal Site

The regulations in 10 CFR 61.44 require that the disposal facility be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care is required. This can involve the use of a grouted wasteform and the addition of an engineered cap on top of the closed facility or tank. The staff should ensure that DOE implements the approach analyzed in the TER to achieve stability of the disposal facility (see Section 7). The staff should also monitor any reports or relevant information regarding whether the proposed approach is in fact providing stabilization. For example, if concrete vaults are relied on to provide stability for a disposal facility, staff should review information to assess that the concrete is performing as expected. Reviewers also should evaluate new information developed about erosion, flooding, seismicity, or other destabilizing processes that may occur at the site (see Section 7).

10.4 Noncompliance Reports

The NDAA requires that NRC provide a noncompliance report to Congress, the State, and DOE as soon as practicable after a noncompliance is discovered (see appendix). A noncompliance exists when there is no longer reasonable assurance that the performance objectives can be met. For example, a significant change in the inventory disposed of, or an analysis that shows that the hydraulic properties of the wasteform are different from those assumed in the waste determination, may lead to estimated doses that exceed the performance objectives of 10 CFR Part 61, Subpart C.

The noncompliance report should provide the NRC's analysis of why it is believed that DOE is not in compliance. The draft noncompliance report should be provided to the State for review and comment. Prior to issuing the final report, NRC staff will meet with DOE and the State to discuss its findings and provide DOE with an opportunity to present any information that may be relevant to the NRC findings. The final noncompliance report should be made publicly available in ADAMS.

The final noncompliance report should be signed by the Chairman of the Commission and, as required by the NDAA, should be sent to the Congressional committees of the Committee on Armed Services, the Committee on Energy and Commerce, and the Committee on Appropriations of the House of Representatives, and the Committee on Armed Services, the Committee on Energy and Natural Resources, the Committee on Environment and Public Works, and the Committee on Appropriations of the Senate. Because NRC does not have regulatory or enforcement authority over DOE, it is the role of Congress, the State, and DOE to determine what, if any, actions will be taken in response to a noncompliance report. NRC staff should continue its monitoring of DOE's disposal actions after issuance of the noncompliance report.

10.5 References

U.S. Nuclear Regulatory Commission (NRC). "Disposal of High-Level Radioactive Wastes in a Proposed Geological Repository at Yucca Mountain, Nevada." Proposed Rule. *Federal Register*. 64 FR 8640. February 1999.

———. "Decommissioning Criteria for the West Valley Demonstration Project at the West Valley Site: Final Policy Statement." *Federal Register*. 67 FR 5003. February 2002b.

———. "Technical Evaluation Report for the U.S. Department of Energy, Savannah River Site Draft Section 3116 Waste Determination for Salt Waste Disposal." Letter from L. Camper to C. Anderson, DOE. December 2005.

APPENDIX: Section 3116
of the Ronald W. Reagan National Defense Authorization Act
for Fiscal Year 2005

SEC. 3116. DEFENSE SITE ACCELERATION COMPLETION.

(a) IN GENERAL- Notwithstanding the provisions of the Nuclear Waste Policy Act of 1982, the requirements of section 202 of the Energy Reorganization Act of 1974, and other laws that define classes of radioactive waste, with respect to material stored at a Department of Energy site at which activities are regulated by a covered State pursuant to approved closure plans or permits issued by the State, the term `high-level radioactive waste' does not include radioactive waste resulting from the reprocessing of spent nuclear fuel that the Secretary of Energy (in this section referred to as the `Secretary'), in consultation with the Nuclear Regulatory Commission (in this section referred to as the `Commission'), determines--

(1) does not require permanent isolation in a deep geologic repository for spent fuel or high-level radioactive waste;

(2) has had highly radioactive radionuclides removed to the maximum extent practical; and

(3)(A) does not exceed concentration limits for Class C low-level waste as set out in section 61.55 of title 10, Code of Federal Regulations, and will be disposed of--

(i) in compliance with the performance objectives set out in subpart C of part 61 of title 10, Code of Federal Regulations; and

(ii) pursuant to a State-approved closure plan or State-issued permit, authority for the approval or issuance of which is conferred on the State outside of this section; or

(B) exceeds concentration limits for Class C low-level waste as set out in section 61.55 of title 10, Code of Federal Regulations, but will be disposed of--

(i) in compliance with the performance objectives set out in subpart C of part 61 of title 10, Code of Federal Regulations;

(ii) pursuant to a State-approved closure plan or State-issued permit, authority for the approval or issuance of which is conferred on the State outside of this section; and

(iii) pursuant to plans developed by the Secretary in consultation with the Commission.

(b) MONITORING BY NUCLEAR REGULATORY COMMISSION- (1) The Commission shall, in coordination with the covered State, monitor disposal actions taken by the Department of Energy pursuant to subparagraphs (A) and (B) of subsection (a)(3) for the purpose of assessing compliance with the performance objectives set out in subpart C of part 61 of title 10, Code of Federal Regulations.

(2) If the Commission considers any disposal actions taken by the Department of Energy pursuant to those subparagraphs to be not in compliance with those performance objectives, the Commission shall, as soon as practicable after discovery of the

noncompliant conditions, inform the Department of Energy, the covered State, and the following congressional committees:

(A) The Committee on Armed Services, the Committee on Energy and Commerce, and the Committee on Appropriations of the House of Representatives.

(B) The Committee on Armed Services, the Committee on Energy and Natural Resources, the Committee on Environment and Public Works, and the Committee on Appropriations of the Senate.

(3) For fiscal year 2005, the Secretary shall, from amounts available for defense site acceleration completion, reimburse the Commission for all expenses, including salaries, that the Commission incurs as a result of performance under subsection (a) and this subsection for fiscal year 2005. The Department of Energy and the Commission may enter into an interagency agreement that specifies the method of reimbursement. Amounts received by the Commission for performance under subsection (a) and this subsection may be retained and used for salaries and expenses associated with those activities, notwithstanding section 3302 of title 31, United States Code, and shall remain available until expended.

(4) For fiscal years after 2005, the Commission shall include in the budget justification materials submitted to Congress in support of the Commission budget for that fiscal year (as submitted with the budget of the President under section 1105(a) of title 31, United States Code) the amounts required, not offset by revenues, for performance under subsection (a) and this subsection.

(c) INAPPLICABILITY TO CERTAIN MATERIALS- Subsection (a) shall not apply to any material otherwise covered by that subsection that is transported from the covered State.

(d) COVERED STATES- For purposes of this section, the following States are covered States:

(1) The State of South Carolina.

(2) The State of Idaho.

(e) CONSTRUCTION- (1) Nothing in this section shall impair, alter, or modify the full implementation of any Federal Facility Agreement and Consent Order or other applicable consent decree for a Department of Energy site.

(2) Nothing in this section establishes any precedent or is binding on the State of Washington, the State of Oregon, or any other State not covered by subsection (d) for the management, storage, treatment, and disposition of radioactive and hazardous materials.

(3) Nothing in this section amends the definition of `transuranic waste' or regulations for repository disposal of transuranic waste pursuant to the Waste Isolation Pilot Plant Land Withdrawal Act or part 191 of title 40, Code of Federal Regulations.

(4) Nothing in this section shall be construed to affect in any way the obligations of the Department of Energy to comply with section 4306A of the Atomic Energy Defense Act (50 U.S.C. 2567).

(5) Nothing in this section amends the West Valley Demonstration Act (42 U.S.C. 2121a note).

(f) JUDICIAL REVIEW- Judicial review shall be available in accordance with chapter 7 of title 5, United States Code, for the following:

(1) Any determination made by the Secretary or any other agency action taken by the Secretary pursuant to this section.

(2) Any failure of the Commission to carry out its responsibilities under subsection (b).